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PAPERS

READ BEFORE THE

ENGINEERING SOCIETY

OF THE

SCHOOL OF PRACTICAL SCIENCE

TORONTO

PRICE, - - - - 50 CENTS.

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PREFACE

The present volume contains the papers read before the Engineering Society of the School of Practical Science during the session of 1899-1900.

As heretofore, the papers all deal with some branch of engineering. Besides being interesting reading, all contain valuable information and will, it is believed, be found useful not only by students but also by graduates and others engaged in active professional life. The several papers on the utilization of hydraulic power, —a subject hitherto somewhat neglected by those writing papers for the Society,—marks a growing interest in a branch of engineering of daily increasing importance, and one that promises to be a most important factor in the development of our country.

The Society is to be congratulated on having secured papers from Mr. Cecil B. Smith, late Assistant Professor of Engineering at McGill University, Dr. P. H. Bryce, Secretary of the Provincial Board of Health, and Mr. A. W. Campbell, Provincial Road Commissioner, each a recognized authority on the subject of which he writes.

The thanks of the Society are due to all who have, by their contributions, materially aided its usefulness.

The present edition consists of 1,500 copies.

Toronto, April 5th, 1900.

CONTENTS

		Page.
President's Address	Thos. Shanks, '99	1
Aerial Cableways	W. E. Wagner, '99	10
The Problem of Speed Regulation in Plants Driven by Water Power	W. A. Hare, '99	37
Cold Storage	E. Richards, '99	76
Hydraulic and Electric Elevators	L. B. Chubbuck, '99	91
Circulation in Water Tube Boilers	W. Monds, '99	112
Some Notes on Bridge Drafting	R. K. Palmer, B.S. (U. of M.)	119
Notes on the Geology of Rossland Ore Deposits	E. Andrews, '97	128
Mine Timbering	E. V. Neelands, '00	137
A Trip to the Yukon	L. B. Stewart, D.L.S., D.T.S.	145
Canadian Steam Railways	C. B. Smith, Ma. E. (McGill)	158
Roadmaking	A. W. Campbell	167
Principles of Ventilation in their Application to Public Buildings	P. H. Bryce, M.A., M.D.	174
Notes on the Development of Water Power	T. Barber, '99	189
Fire Making	W. H. Ellis, M.A., M.B.	201
Tensile Strength of Rivets and Bolts	D. C. Tennant, '99	206
The Strength of Glass	C. H. C. Wright, B.A.Sc.	221
Index to the First Thirteen Numbers		223

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ENGINEERING SOCIETY

OF

The School of Practical Science

TORONTO.

PRESIDENT'S ADDRESS.

I thank my fellow-members of the Engineering Society for the honor they have conferred upon me in electing me to the Presidency for the current session, and am encouraged to hope that their continued assistance and co-operation will enable me to discharge the duties of the office in such a way that our Society shall not be retarded in that influential development which has been so markedly characteristic of it since its organization.

As this Society is recognized as the representative student society of the School I wish to refer first to some matters of general interest to the student body, and, indeed, to our whole membership.

The proposal to form an Engineering Corps in the School has met with your unanimous approval, and it is to be hoped that the proper authorities will soon carry the idea into effect.

The growing importance of the work done in the School, as evidenced by a constantly increasing attendance of students, is a gratifying feature, and has given rise to a crying need for greater accommodation. Provision must soon be made to relieve the uncomfortable overcrowding in the drafting rooms.

The students of the School have always taken a prominent part in athletic sports, and the various teams made up from our members have won more than a local reputation for their prowess on the field. In athletics, as in all events where *esprit de corps* has been

a necessary factor to success, the characteristic unity of our students has been most commendable, and we are pardonably proud of the fact that "the School" has become synonymous with all that is desirable in college camaraderie.

I welcome to our Society the students of the first year, who are soon to become members, and I trust they will find our meetings both pleasant and profitable, and that they will do their utmost to promote the prosperity of our organization.

One of the most satisfactory features in connection with our work is that every student of the School of Practical Science is recognized as a member of this Society. In this connection the Council of the School have taken every opportunity to impress upon the students the fact that a hearty co-operation in the active work of this Society is an essential part of their regular work, and have not only allowed a portion of the school time to be used for the meetings, but have given us more substantial encouragement by taking the papers read by students into account in determining Honor standing. It is very gratifying to know that many of our members have availed themselves of the privilege thus accorded them, and a perusal of our last year's pamphlet will serve to show to what a great extent the success of the year's work was due to undergraduates of the School, and to the impetus given the Society by this generous action of the Council.

In speaking to you this afternoon I have selected for a subject, "Science, in Theory and in Practice." For the ideas here expressed I do not lay claim to any particular degree of originality, and therein may lie their chief merit. If they arouse thought and discussion, even if they provoke opposition or adverse criticism, they will have served a useful purpose.

We hear much of the distinction made between pure science and applied science; between the study of theorems, principles, and laws, and the applications of these to the needs of civilized life. Some magnify the former, and some exalt the latter. The defender of the one is ready to subscribe to the declaration of the American scientist that "the cook who invents a new and palatable dish for the table benefits the world to a certain degree; yet we do not dignify him by the name of a chemist;" while the advocate of the other agrees with the French magistrate who held that "the discovery of a

new dish is more important than the discovery of a new star, because there never can be dishes enough, but there are stars enough already."

Our position as graduates and undergraduates of an institution in which practical science is taught, should lead us to consider our relations to the rival camps, and to enquire what cause for strife exists.

To those who are willing to obtain all their information from a name alone, the words "practical science," must be very misleading. Such philosophers will have reason to join Carlyle in his denunciations of that "mechanical manipulation falsely named Science," and will be justified in railing against the baneful and degenerating influences of modern education. They will be free to conjure up visions of a system in which empirical device and rule-of-thumb experience are substituted for accurate knowledge and scientific reasoning.

There are those, again, to whom the word "Science" is suggestive of dim, visionary, and unpractical ideas. To them the scientist is an eccentric and absent-minded dreamer—harmless, but useless. They value the invention of a burglar-proof lock more than the discovery of the law of gravitation. They prize any knowledge only in the degree in which it can be applied in the various branches of human industry, and argue that practical education should be directed with special reference to some gainful pursuit.

Science may be defined as systematized knowledge—knowledge of phenomena collected by careful observation and experiment, and knowledge of the laws by which these phenomena are controlled and co-related. Science is not confined to the narrow region of the known, but is constantly endeavoring to explore the greater field of the unknown, and to connect the two by basic principles common to both. The observer, the experimenter, and the philosopher must all be combined in the man of science in order that facts and phenomena which are met with at every turn, may be properly noticed and collected, that the knowledge obtained may be arranged and recorded, that underlying relations may be studied and defined, and that the laws thus ascertained may be used in further discovery and research. The scientific mind must be a judicial one, unhampered by the distorting influences of prejudice or of habit, always

willing to weigh any evidence which may be submitted to it, prepared to test that evidence by all available means, and free to accept conclusions which are thus established.

As has been indicated, science should promote discovery and research, and herein lies its practical application and its connection with art to which it can never be antagonistic. The comparison which has been made between pure science and its applications shows that the latter, when slavishly followed may degenerate into mere manipulation, just as abstract science, falsely understood, may be transformed into a sort of dreamy abstraction, productive only of the be-spectacled bookworm, or into a sort of narrow-gauge specialism which frequently gives rise to vain theorizings, or to the blind gropings of the inventing crank. Art and Science have mutual relations, and if in the past the former has been the parent and not the progeny of the latter, it has been owing to the fact that scientific methods were not used in advancing science. In late years a great change has been brought about, and it may reasonably be expected that in the future we shall see science leading and directing. The older methods whereby undefined results were attained by discouraging and laborious efforts, will give place to an intelligent seeking out of practical ends by logical and scientific processes. The engineer will not stumble along in guesswork and speculation, but will design intelligently.

This union of science and art may be noted as a distinguishing characteristic of the present age. Many of the philosophers of the olden times held art in supreme contempt, and valued science only as useful for mental gymnastics, and not for its knowledge of facts and phenomena, and for its practical applications. The inutility of scientific achievements was their chief claim to appreciation, and it is said that even Archimedes was much prouder of his discovery of the relation between the volumes of the cylinder and the sphere than of his enunciation of the principle of the lever that might have relieved Atlas of his burden. It is said that many of the ancient Greek philosophers entertained, in regard to physics and mechanics, the fallacious notion of the existence of a double system of laws; one theoretical, discoverable by contemplation and applicable to celestial bodies, the other mechanical, discoverable by experiment, and applicable to terrestrial bodies. It was many years later that the science of

motion, founded by Galileo, and perfected by Newton, overthrew this supposition and proved that celestial and terrestrial mechanics are branches of one science. As a result, development, in these olden times, was metaphysical rather than practical, and the study of physical science was avoided as being too utilitarian. Study and meditation were divorced from experiment and observation, and the practical man was left to plan and invent without the assistance of the rudiments of a true scientific education. Thus it was that art, progressive and enthusiastic, prompted by the demands of practical life and striving to supply these new and increasing demands as new conditions were established, was left to grope its way unaided by science. Gunpowder was known long before a Lavoisier lived to teach the science of chemistry; steam was used as a motive power years before the science of thermodynamics had been thought of; many of the modern marvels of invention and discovery were being gradually developed by men who were artisans rather than scientists. An evolution was in progress, however, and indefinite knowledge and inaccurate reasoning were slowly giving way to skilled observation, clear thought, and scientific invention. Such men as Galileo, da Vinci, and Newton, who were mechanicians as well as philosophers, laid the foundations for the practical applications of science, and every phase of human industry soon felt the stimulus given by the new methods. Old theories handed down as an accumulation from the preceding centuries were closely examined in the light of new discoveries. Many were rejected to make room for their more rational successors and the survivals of the old science and the creations of the new were subjected to the severest tests of critical investigation.

The new science gave rise to new arts and led to a more complete and systematic development of those about which important facts had already been collected. Experimental work was commenced in fields hitherto untouched, and our knowledge of the common things of daily life and work was rapidly extended and systematized.

It seems evident that the recent advance of both science and art has been largely the result of a closer union of the two, and the great future of both undoubtedly depends upon the cultivation of each in relation to the other,—the science enabling us to promote every department of human industry and the art providing us with new

and interesting problems which can be solved only by the application of well-established scientific principles. The educational world has not been slow to recognize that a study of the natural and physical sciences is just as instrumental in strengthening the intellect and broadening the mental view of the learner as knowledge and discussion of the more popular speculative subjects of the past.

It is in the engineer, "the ingenious man," that this union of science and art should have its highest development. "When science—the accurate knowledge of what others have done—and experience—the knowledge of what we ourselves have done, are united in the one person, then we may safely say that we have seen the evolution of engineering from a craft to a profession. The only sound engineering progress is that which harmonizes with and therefore advances the great economic evolution which is moving so rapidly in the modern world. Engineering is in fact applied economics."

An engineer must possess an accurate knowledge of those principles, theories, and laws which have been the subject of long-continued discussion, experiment and study, but he must also be able to carry this knowledge into professional or business life, and to apply it in actual construction or design. However remarkable some of the products of engineering skill may be, they are not creations but developments; they are the results of the application of scientific data and a knowledge of natural laws, and no matter how great a genius the engineer may be, he cannot afford to discard those great principles which have been formulated in the system of pure science.

There is a large field in engineering for the man who can devote his time and ability to purely scientific and experimental work. There is much to be done in the lines of research and investigation that cannot be done by the practising engineer. Many old problems are still unsolved and new ones are constantly arising as a result of new conditions. The laboratory must frequently serve as the engineer's court of appeal and the work done there should direct and supplement that done in the office and in the field. The mathematician is as essential as the mechanic. The narrow practical man is prone to depreciate the value of his co-worker in the study or the laboratory, and the man of abstract science too often underrates the value of the mechanical or utilitarian side of the subject.

It should be the aim of every engineer to reconcile and co-ordinate the two great phases of professional work and to remember that the theoretical and the practical are mutually dependent in order that each may have its fullest development. The history of astronomical study provides a striking illustration of this in what was probably the most remarkable discovery of the present century—that of the planet Neptune. Each of the great mathematicians—Adams, in England, and Le Verrier in France, determined by calculation the position of this planet in the sky before it had ever been seen by the eye of man, and it only remained for the astronomer to institute the telescopic search and to verify the results obtained in the study by the discovery of the planet in the exact spot which the mathematicians had indicated. The importance of the discovery consisted not so much in the fact that a new planet had been added to the list, as in the new proof which it revealed of the truth of Newton's law of gravitation upon which the calculations had been based.

Science promotes material prosperity and commercial interests help science. The man who works with the hope of pecuniary reward sometimes aids the advancement of knowledge quite as much as the disinterested and self-sacrificing toiler who devotes his life to the cause of research. The former is likely always to remain the type of a more numerous class, and one of the great problems before us is to render the work of these men more useful in the cause of scientific advancement. I think we ought to feel that one of the most important lessons that a technical school such as this can teach us is to constantly work with a sense of the great obligations which we owe to pure science, to make it our aim in professional work to apply the teachings of well-established truths, and to strive to add our quota, however humble it may be, to the sum of human knowledge by observing and recording the varied facts which are sure to confront us in the many problems of daily existence.

This is called the age of invention, and in many quarters a deep-rooted impression prevails that the inventor has done his work not with the assistance of the teachings of science, but rather in spite of them. We owe much of our modern material progress to the genius of invention, but we must also acknowledge that every great invention has been based upon well-known natural laws which have been deduced by scientific men from observed facts. The inventor

attempts to turn these scientific discoveries to practical account. He fails and a successor takes up his work, familiarizes himself with the methods of his predecessor and introduces improvements. The failures of unsuccessful investigators become the stepping-stones to ultimate success. In invention it is particularly true that "art is long," and it is remarkable what a great mass of facts must be collected, and what a great number of minds must be engaged before the finished triumph is reached. The completed design rarely comes suddenly, as by inspiration, but depends for its complete development upon science intelligently applied, and upon a knowedge of what other workers in the same field have done. Herbert Spencer says that the knowledge we inherit represents the accumulated experiences of a thousand generations. We are told that it required seventy years and hundreds of patents to get the now familiar sewing machine into workable shape, and that the persistent efforts of various inventors during a period of seventy-five years were necessary before the reaping machine could be turned to practical use. The history of these and of many other inventions teaches us the great importance of being fully equipped for any work by learning both the theory and the practice connected with it.

The practical man who rejects the use of any principles except those of trial and error, and who does not see that many of the practical problems of engineering are intimately connected with the most important scientific theories and laws, deprives himself and his profession of that healthy development which always accompanies true life. On the other hand the theorist whose resources are limited to speculative discussions of scientific theories and mathematical formulæ, and who regards their practical application as little short of sacrilege, retards that true progress which he professes to promote.

In conclusion let me quote the words of Professor Rankine, to whom the engineering profession is so much indebted:

"The cultivation of the harmony between Theory and Practice in Mechanics—of the application of Science to the Mechanical Arts—besides all the benefits which it confers on us, by promoting the comfort and prosperity of individuals, and augmenting the wealth and power of the nation—confers on us also the more important benefit of raising the character of the mechanical arts, and of those who practise them.

"Every structure or machine, whose design evinces the guidance of science, is to be regarded not merely as an instrument for promoting convenience and profit, but as a monument and testimony that those who planned and made it had studied the laws of nature; and this renders it an object of interest and value, how small soever its bulk, how common soever its material.

"For many years there has stood in a room in Glasgow University, a small, rude, and plain model, of appearance so uncouth, that when an artist lately introduced its likeness into a historical painting, those who saw the likeness, and knew nothing of the original, wondered what the artist meant by painting an object so unattractive.

"But the artist was right; for years ago a man took that model, applied to it his knowledge of natural laws, and made it into the first of those steam engines that now cover the land and the sea; and ever since, in Reason's eye, that small and uncouth mass of wood and metal shines with imperishable beauty, as the earliest embodiment of the genius of James Watt.

"Thus it is that the commonest objects are by science rendered precious; and in like manner the engineer or the mechanic, who plans and works with understanding of the natural laws that regulate the results of his operations, rises to the dignity of a Sage."

THOMAS SHANKS.

AERIAL CABLEWAYS.

W. E. Wagner, Grad. S. P. S.

Wire rope cableways as a means of transportation have been used extensively by European engineers during the past twenty years, but it is only recently that they have been adopted to any considerable extent in this country.

The original method in America was to have a single cable, carrying only one load at a time, but this proved such a slow means of conveyance that it was very little used. Later the method was improved so that a continuous line of buckets might be used, increasing according to the number of extra buckets the original discharge. This is made possible by the means used to connect the buckets on carriers to the cable, so that they may pass easily over the pulleys and around the terminal sheaves.

A commoner method, used extensively in Europe, and which has been the principal agent for the adoption of cableways in America, is to use a stationary cable (or if the load exceeds five or six tons, two stationary cables) and a running endless rope. Carriages running on the stationary cable, are attached to the endless rope by friction grips, or other appliances, which work automatically, letting go of the hauling rope at desired points. The first method is cheaper where practicable and when a large capacity is not required, for it can only be run at a very slow speed and is much less economical for heavy duty.

Stationary cables as a rule are used for short lines with heavy loads, or for very long lines.

SINGLE ROPE CABLEWAYS.

The buckets in these lines may either be fastened rigidly to the cable, or carried along by friction only. The latter method, which is by far the most convenient one, is very seldom, if ever, seen in America, but in Europe it is generally chosen where

the quantity to be carried does not exceed 500 tons per ten hours, where the inclines do not exceed one in three, where the individual loads are not greater than 600 lbs., and also where the section of ground does not necessitate spans of greater length than 600 feet.

The saddle in an iron frame is fitted with wood, or rubber, or composition friction blocks, by means of which the necessary friction on the rope is obtained. The frame which carries these friction pieces is fitted with two small wheels, carried on pins attached to it. These shunt wheels are employed for removing the carrier from the rope at the loading stations and at curves, where shunt rails are placed. These rails are held in such a position that when the carrier approaches, the small wheels engage on it, and running up a slight incline, lift the friction saddle from the rope, and enable it to pass to where the loading and and unloading is required to be done.

The impetus derived from the speed of the rope (about four miles an hour) is sufficient to enable the carrier to clear itself automatically. The buckets which carry the material, are attached by means of hooks to curved hangers, pivoting on the V shaped saddles.

The other features of the ropeway consist of a driving gear at one end, fitted with a horizontally placed sheave, five to ten feet in diameter, depending on the size and construction of the cable used. The power may be supplied by steam, water, compressed air, or even horse power in the case of smaller lines.

At the opposite terminal, there is a similar wheel, provided with tightening gear, and around the two sheaves an endless band of wire rope is placed. The lower terminal generally runs on tracks, and the tightening gear in such cases, consists of a strong wooden box, filled with rocks or old iron, and hung in a wooden frame-work. The weight of this box, acts through a wire rope about suitable pulleys so as to always maintain the same tension in the line under any conditions.

Intermediately between these stations, the wire rope is carried on suitable pulleys, placed on frames of iron or timber, spaced about 200 feet apart, and of suitable height to allow the carriers to clear intervening obstacles, and also to regulate as much as possible the general level of the line. It is economical and good practice to place the towers as far apart as possible, for there is less wear on the

moving ropes, and they run quieter, and with fewer jerks than when closely spaced.

Where the country is level the supports cannot be placed very far apart, on account of the sag in the rope, unless the towers be made very high, so the span and the height of the towers becomes a question in each case of economy and convenience.

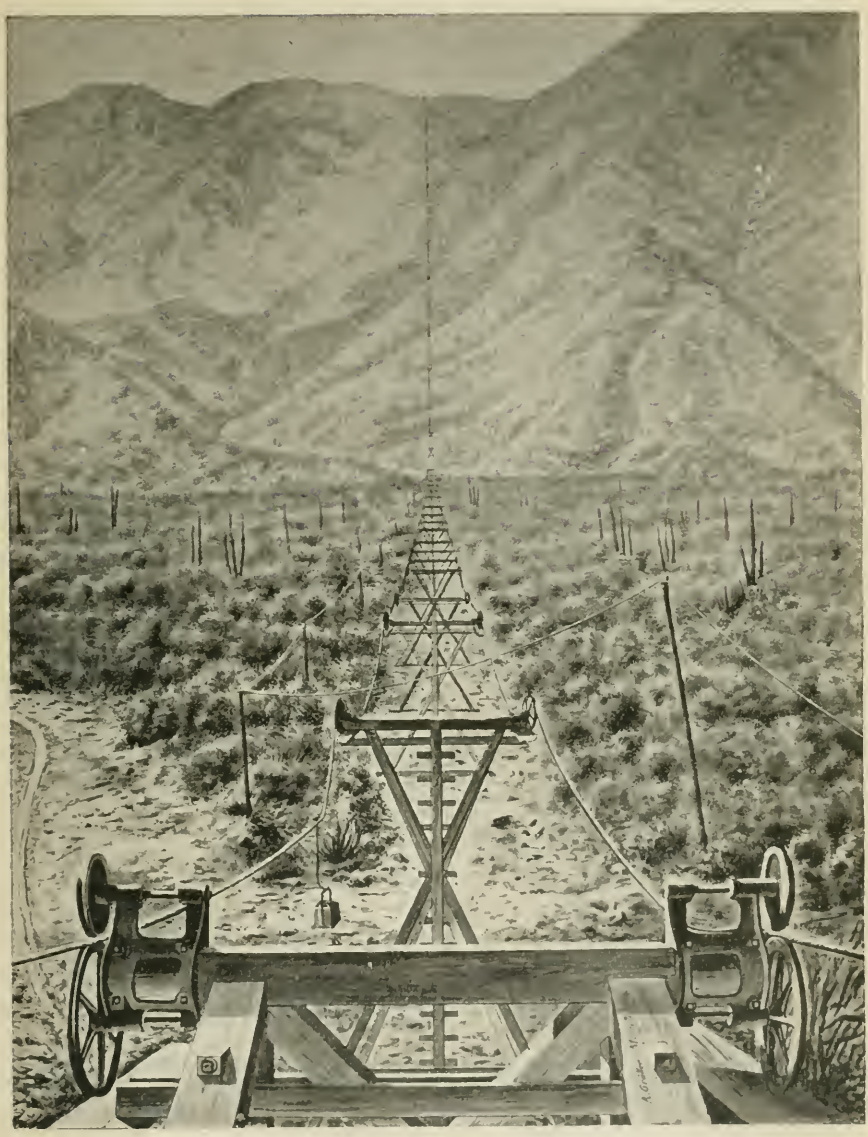
In general the towers are of no particular structure, made of four heavy timbers, braced together to suit their position, and carrying a cross piece for the pulleys. Where there is danger of snow slides, a single post is sometimes used, as it offers less resistance and is not so liable to be swept away.

Fixed carriers are specially suitable where the country is very hilly, and very steep inclines are liable to occur in the line. The friction carriers are limited to small grades, but the incline on which these lines will work seems to have no limit.

Where the ground is so uneven as to necessitate sudden changes in the vertical angle of the line, guard pulleys may be used, which depress the rope until the load passes, when its weight relieves the pressure on the guard wheels and enables it to pass under.

The carrier is fastened to the cable, either by using a steel clip, with suitable corrugations, to be inserted between the strands of the cable; or by tightening a steel band about the rope by means of a shank and key. Tests have been made on these clips under hanging loads, and they are found to sustain weights up to 1,500 lbs. without showing any weakness, or injuring the rope. This is amply strong enough, for the loads on these lines rarely exceed 500 or 600 lbs., while experience proves that loads ranging from 100 to 200 lbs. are the most economical.

For steep inclines or heavy duty, special terminal sheaves are employed at the driving end, and sometimes at both ends, to prevent the cable slipping. These "grip sheaves" are automatic in their operations having a set of teeth working in the circumference. The pressure of the cable on the bottom of the jaw causes the teeth to close upon it, securing a grip, that makes slipping impossible; and on the pressure of the rope being removed, the teeth spring open and release it.



SINGLE ROPE CABLEWAY BUILT BY CALIFORNIA WIRE WORKS.

When the point of discharge is lower than the loading point and the delivery is five tons or more per hour, the line will operate by the weight of the descending load under ordinary conditions, providing the grade exceeds eight degrees or one in seven. In such cases the speed of the line is controlled by a wood-lined band brake, operated by hand at the upper terminal, and occasionally for very heavy lines a brake is also needed at the lower end.

A remarkable instance of this is a ropeway in Japan, about 1,800 yards in length, for the greater part on an incline of one in one and a half. Such is the power generated by the descending loads, that it is necessary to absorb the greater portion of it, and thus render the line amenable to a hand-brake. The power could not be usefully employed, so a water-brake was introduced, in which a revolving fan drives the water against fixed vanes, which again repel it. In this way some 50 h.p. are absorbed, and the speed of the ropeway can be regulated exactly, by adjusting the re-action vanes. A small supply of cold water is provided to keep the temperature of the water employed in the brake, sufficiently low.

Sometimes the extra power thus afforded may be used to carry back and up such material as may be needed; and in some cases this extra power actually becomes a source of revenue. There are mines, where the descending ore even supplies enough power to operate a rock-crusher. In some cases where the grade is not quite sufficient for this, extra power may be supplied to the cable at the lower terminal, and transmitted through it to machinery above, without in any way interfering with the regular duty of the ropeway.

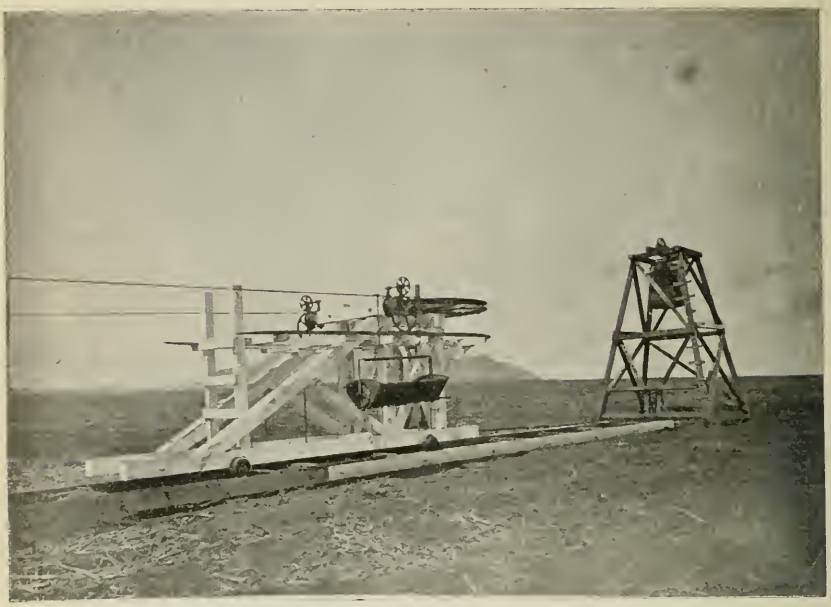
As has been mentioned the friction carriers may be shunted off the line and brought to rest at loading stations, but when fixed carriers are employed this is impossible, and all the loading and unloading must be done while the bucket is in motion, consequently the speed of the line generally ranges between two and four miles per hour. It is a simple matter to dump the buckets automatically by means of a fixed rod at the discharge terminal, which releases a catch and allows the bottom to open, and the contents drop out; then as soon as it is empty a counterweight at the back closes the bottom again and it is ready for loading.

The loading is generally done by hand, but where the material to be handled is of a uniform character such as coal or ore, some very

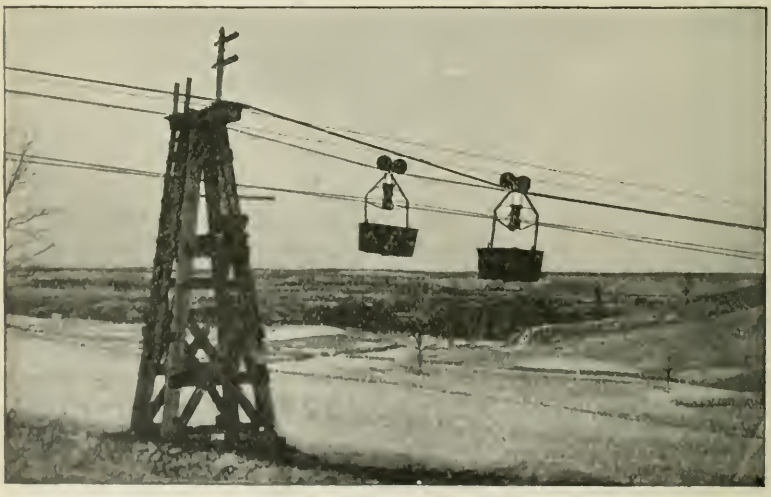
ingenious methods of automatic loading have been devised. A very good example of a loader, is one built by the Hallidie Wire Ropeway Co. of California. It consists of a pendulum made from sheet iron tubing 12 ins. in diameter, swinging on trunnions about 20 feet above the level of the moving cable. At the lower end is attached a loading box, which contains when loaded, enough ore to fill one bucket of the ropeway. The loader hopper has two sides, a back, and a sloping bottom, the front being open. While the hopper is being loaded, it is held between a guide and a fixed door or bulkhead, which closes the open front.

The releasing of the hopper box is done by a clip on the moving cable to which the ore carrier is suspended, and which as it moves along strikes the end of a lever which raises the latch off its keeper. At the time the loading box is released the ore carrier is immediately under the nose of the loader box, ready to catch its contents. The clip on the moving cable then pushes the hopper out from behind the fixed door, at the same speed as the carrier, and thus opens up the front of the loader box and lets the contents pour into the carrier. The swing of the pendulum raises it sufficiently high, after a few feet of travel to clear the rope clip, and the pendulum with the empty hopper swings back by gravity, in between the guide and the bulkhead, ready to receive another load of ore from the ore bin.

With the friction clip as was seen, it is a comparatively simple matter to make a turn in the line, but with fixed carriers, an angle station of special construction is required, which greatly increases the cost of the line. This is due to the position of the clips and hangers. As they hang on the outside of the rope, it is necessary to have all the supporting sheaves and horizontal sheaves on the inside. In arranging a turn, one line, which should be the loaded one, can be carried around a horizontal sheave all right, but the inner rope must be carried across and over the loaded rope to a turning station, whence after passing around a horizontal sheave, it returns crossing the loaded rope and itself near the first sheave, and goes on to the next regular tower. This tower must be sufficiently high to allow the ropes to clear each other by seven or eight feet, and prevent the buckets fouling with the rope beneath. Sometimes two turning stations instead of one are used; this requires more structural work but makes a simpler turn.



TERMINAL STATION.



DOUBLE ROPE CABLEWAY, BUILT BY TRENTON IRON CO.

Another point in favor of the friction grip is that lines using them may be of unlimited length, for stations may be placed at intervals along the line and the buckets switched automatically from one cable to the next. However this advantage is of little practical use, as cableways are seldom used of more than a mile or two in length, and single cables have been made to cover as much as five miles.

In the south these cableways are used extensively for transporting sugar cane from the fields. The loading is done altogether by hand, the cable being lowered on to a portable tower, which may be placed at any point in the line, so as to keep in touch with the work. Sometimes all the towers are movable and the whole line swings around in an arc, bringing the line to bear on every part of the field.

Another very convenient method to cover a large area of ground, is to have the line run around a rectangle, in this case only one line is needed, doing away with the necessity of extra stations at the corners.

DOUBLE ROPE CABLEWAYS.

The double rope system consists of two stationary track cables, stretched from one station to the other, over the tops of the towers, an endless traction rope running parallel to the stationary cables, and carriers hauled along the stationary cables by the traction rope, to which they are attached by grips. This system is used where the quantities to be transported exceed 400 tons per day, where the individual loads are more than 600 lbs; also where the inclines exceed one in three, and the spans exceed 600 feet.

Some of the advantages of this system are its capability of carrying loads of 2,000 lbs. or more, very little power being needed owing to the fact that only the carriers, connected by a light hauling rope are moved, and they run with the same ease as a car rolling on a track. On this account, these lines will run by gravity on a less incline than that required by a single-rope line. Long spans are practicable owing to the high tension at which the track ropes are stretched, which lessens the deflection in the rope between the points of support.

Of the two track ropes, one is used by the loaded carriers moving in one direction, and the other by the empty carriers returning.

On this account the return cable may be made of lighter rope, and so economy effected. In like manner when the spans are particularly long, heavy ropes are inserted in the line, so that the track ropes may be fittingly proportioned to the tension they must bear.

The track ropes are rigidly anchored at the upper end of the line, and the lower ends drawn taut by counter-weights. If the line exceeds a mile and a half in length, the track ropes are usually divided into two or more sections with a tension station for each section.

The hauling rope is operated by a suitable driving gear at one end, and controlled by a tightening gear at the other, and moves at a speed of from four to six miles an hour. For very long lines, or for shorter lines, which have a great difference of level between the terminals, stations are placed every 5,000 or 6,000 yards to supply power to the moving cable, but two sections of such a line can always be worked from their intermediate station by the same motor.

The attachment of the carrier to the hauling-rope is an essential point, as it must be made by means of an automatic clip, which will release itself, on touching a bar at the various stations, and at the same time will hold sufficiently tight to enable the hauling-rope to drag the carrier up any incline which may occur in the line. This is done by forming a knot in the hauling-rope, by putting a sleeve around it, or a suitable casting inside, at certain points, so as to make an enlargement which is caught by a suitable device on the carrier. This device sometimes consists of fork shaped pawls, which are thrown in and out of action by engaging with a guide rail at the stations. The speed of the carrier is sufficient to avoid any great impact of the knot with the grip. At the loading stations however, the loads being large, and the carriers starting from rest, a man is required to push off the carrier, when a knot is known to be approaching by the ring of a bell. A better arrangement, which does away with all undue wear in the rope, and is much less jerky, is that of a clip by which the hauling-rope is held simply by pressure.

The "Universal Friction Grip" is a good example of a pressure grip. The main feature is a short shaft on which are cut right and left hand threads of different pitches. This shaft has a bearing secured to the hanger, the nuts for the screw threads being also the jaws of the clamp, by which the rope is gripped. On one

RAISED A X TOWER ON SINGLE ROPE CABLEWAY.

WIRE ROPE TRAMWAY (BLEICHERT SYSTEM).

Length of line 9,000 feet; daily capacity 400 tons. Showing portion of a span 1,173 feet across the town of Wardner, Idaho.

end of the shaft is keyed a double lever, which in its upper end carries a pin, on which is a cylindrical counter-weight free to revolve.

The outer jaw of the clamp has a right-hand thread of very fine pitch, and the inner jaw has a left-hand thread of very coarse pitch.

Suppose the carrier to be in such a position that the hauling-rope passes freely between the open jaws. If the lever is now turned to the right the shaft will revolve and the clamp will close quickly until the jaws come in contact with the rope. At this moment the effect of the coarse-pitch thread on the inner jaw ceases, but the further turning of the shaft causes the outer jaw to continue its motion. Very little movement is now required to clamp the rope tightly; and this is done with all the power due to a fine-pitch screw.

The process of coupling is as follows:—When the carrier is moved from the switch rail of the station on to the carrying rope, the counter-weight on the end of the lever becomes at the same time engaged with a guide rail in an inclined position, and as it rolls up the incline, the lever is caused to turn. When leaving the guide rail the lever will stand about vertical, and in this position the jaws are in contact with the rope, and the coarse-pitch thread in the inner jaw will be out of action. At this moment the lower arm of the lever strikes against a pin, which compels the lever to turn further, thereby clamping the rope tightly by action of the fine-pitch screw in the outer jaw.

The release of the carrier from the rope is caused by a similar inclined guide rail, after leaving which the counter-weight by its gravity, continues to turn the lever, giving a wide opening to the jaws and fully releasing the rope.

As in the case of friction grips on single rope lines, angles may be turned readily by using guide rails, upon which the carriers shunt automatically as explained. Under the "Bleichert" system, controlled by the Trenton Iron Co., shunt rails are also used in passing sharp ridges. These "rail stations" as they are called, consist of a series of bents from 15 to 20 feet apart, supporting rails which overlie the track cables and save them from undue wear at these points.

Although in general the traction rope has only to overcome the inertia of the loads, it must be considerably stronger than is necessary for this, for on inclines it has to support a certain proportion of the weight of the load.

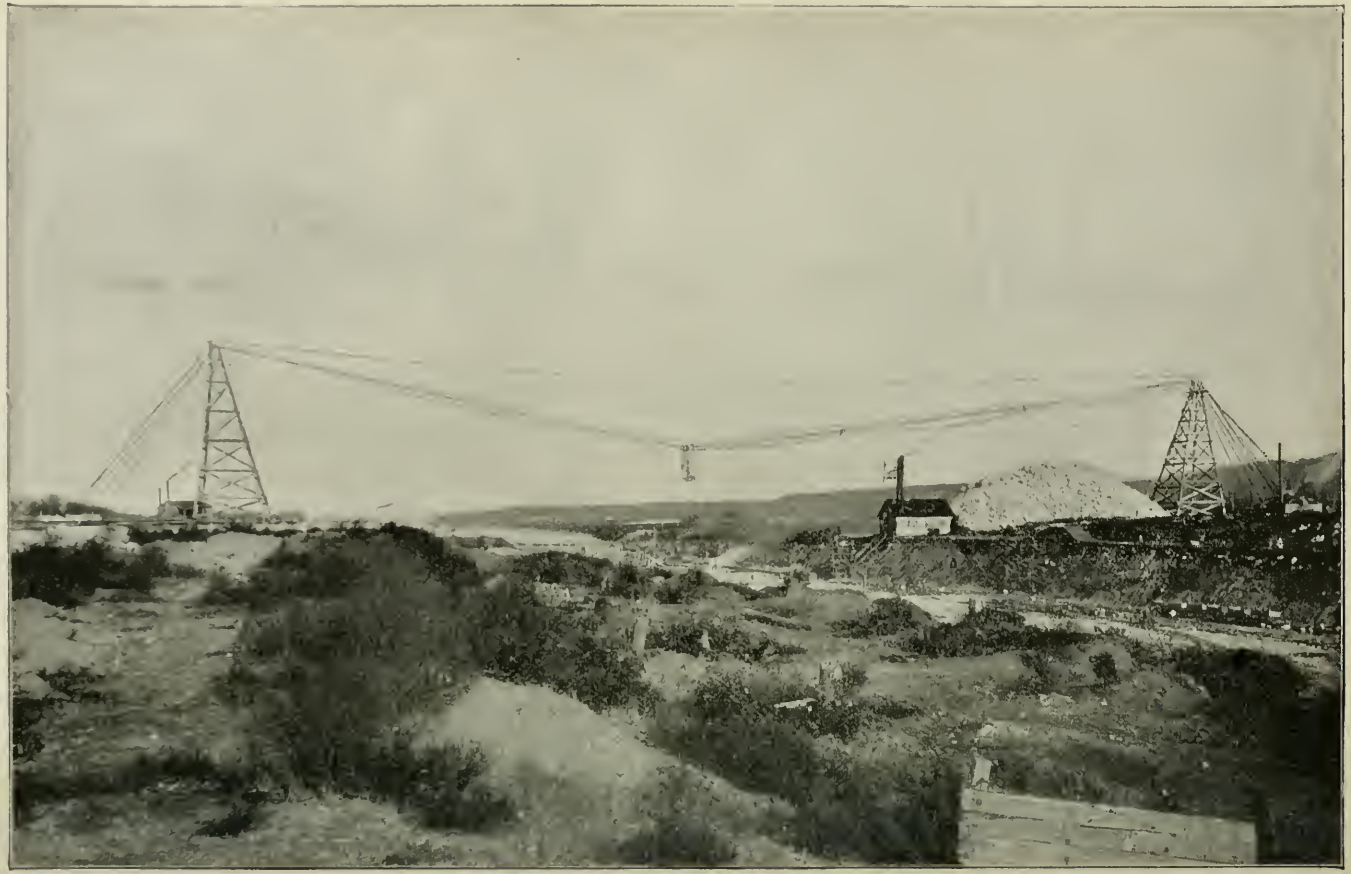
With the "Dusedau" system, under the control of the Broderick and Bascome Rope Co. of St. Louis, the hauling rope is stretched very tight, and supported by pulleys close to the fixed cable, to enable it to take a share of the weight even on level ground. This style of line is most likely better for sloping ropeways, but on the level it must be much less economical, for the great advantage of having a fixed cable is partly lost.

When the quantities to be transported do not exceed 100 tons per day, and are to be moved in loads of 2 to 6 tons at a time, only two carriers are used, one on each cable; and in this case shunt rails are not required at the terminal stations, for when the bucket at the loading station starts on its way, the empty bucket leaves the discharging terminal, passing each other at the center. On arriving at the end of the line, the loaded bucket is dumped, and the empty one filled; then the engine is reversed and the operation repeated.

Where very heavy loads are carried, the length of the line is short, having generally only one span, for it is difficult to pass a heavy load over a support, on account of the shape of the carriage, which in order to carry several tons must be made to straddle the cable. With favorable ground, spans up to 2,000 yards may be made without supports.

While many ropeways of this kind are employed simply to span from the upper portion of a mountain over a valley to the lower side of another, others are constructed with one or more supports, and skirt the side of a steep hill. In this case the loads are less and the speed never exceeds ten miles per hour, whereas with straight lines when run by gravity the speed sometimes reaches thirty or forty miles an hour. As the loaded carrier is usually much heavier than is necessary to draw up the empty one, a proportionate amount of material may be transported up as well as down; in some cases where water is available, it is even possible to run materials up alone, employing the descending carrier as a counter-balance filled with water.

Long spans like those mentioned above reaching up to 2,000 yards, are confined exclusively to European practice, the longest spans in America not exceeding a third of this length.



General View of Travelling Cableway, Chicago Drainage Canal, Section 2.

Sometimes for very steep inclines and long spans where the quantity to be transported is not great, a single cable is used, with a carrier drawn to and fro by an endless hauling rope.

This form of cableway like the one previously described is very little used in America except for logging, and when used for this purpose the construction is very crude, consisting generally of a single span, with trees for terminal posts.

CABLE HOIST-CONVEYORS.

A modification of the single line ropeway has recently come into practice in America for excavating and canal work, being known as the cable hoist-conveyor.

It is used for moving heavy loads of several tons weight over short distances. In cases where the line is of considerable length and it is impracticable to build towers of the requisite height for a single span, intermediate supports may be introduced, but in this case a double line of track cables must be employed on account of the construction of the ordinary carriage which straddles the single cable, and hence would not pass such supports. By using two cables a construction of carriage is obtained in which the wheels that run on the track cables are outside of the carriage frame, which is thus free to pass between the two saddles at the intermediate supports.

These lines as the name implies, not only convey the loads, but hoist or lower them at any point in the span by means of a separate hoisting rope. In inclined lines, where the carriage descends by gravity, this is the only moving rope required, but generally the hoisting and conveying is done by separate ropes.

In either case the track cable rests upon saddles or grooved blocks of hard wood, forming the peaks of the supports, as in the other systems using the stationary cable, and is anchored firmly to the ground at each end, a turn-buckle usually being provided at one end for maintaining the proper deflection. The towers are pyramidal supports of wood or iron as preferred, although in many cases, especially when the loads do not exceed one or two tons, these are simple A frames or masts guyed with wire ropes.

Inclined cable hoist-conveyors have been used largely for quarry work, especially in Pennsylvania, and Vermont.

If the loads are to be elevated from a quarry for instance, a stop or buffer-block is clamped to the track cable at the loading point, which arrests the carriage in its descent, and allows the bucket to drop to the place of loading. The hoisting rope is reeved through the carriage and fall block with a sufficient number of parts so that the hoisting resistance is less than the resistance to traction. Applying power to the hoisting drum, the load rises till the fall block encounters the carriage, when the latter proceeds to move up the line till the point of discharge is reached. Here it engages a latch, clamped to the track cable, which prevents the carriage running back while lowering the load. The power is thrown out as soon as the carriage engages this latch, and the lowering of the load is effected by means of a brake on the drum.

The limiting or least inclination on which such a line will work is about one in three. If the load is a descending one the operation is similar, but in this case lighter inclinations are practicable, the limit being a fall of about one in five for ordinary loads. The power required is considerably less, since it is only applied in raising the loads from the ground.

If it is required to load and unload at various points along an inclined hoist-conveyor the carriage may be attached to an independent rope, operated in conjunction with the hoisting rope, except when raising and lowering the load when it is held by a brake on the drum from which it is driven.

Owing to the steep inclination necessary for the successful operation of these lines, their application is very limited. In most cases the terminal points are on about the same level so that the movement of the carriage must be effected by means of an independent rope and drum.

Besides the hoisting rope these lines are sometimes provided with a dump-line, which is attached to the rear end of the skip. When it is desired to dump the latter, this line is drawn in at a higher rate of speed than the hoisting and hauling ropes, by being thrown on a drum of larger diameter. Thus the skip is tilted and the load dumped without stopping the carrier. In these lines, employing both a hoisting and a hauling rope a "fall-rope carrier" is employed to prevent them sagging, which they would do, being under very low tension.

Travelling Cableway, Showing Completed Rock Cut, Chicago Canal, Section 8.

The immense importance of these fall-rope carriers will be seen when it is considered that if the fall-rope were allowed to sag down for any distance it would be impossible to lower the fall block and the cableway would be inoperative, in addition to which would be the great wear on the rope from dragging on the ground.

These rope carriers must of course be movable in order to make way for the load. When the load is drawn in towards the terminal, the carriage gathers the rope carriers up in front of it, and when after dumping its contents the empty bucket returns towards the loading point the rope carriers are deposited one by one at the required places, either by being joined together and to the terminal station by a rope, or by being displaced from a horn on the front of the carriage by steel buttons fastened to a special button-rope. The spaces in the carriers are graduated in size as are also the buttons on the button-rope, so that each button will pass through every rope carrier except the one it displaces from the carriage.

In the "Laurent-Cherry" system controlled by the Trenton Iron Co., these rope carriers are dispensed with altogether.

In this system the arrangement of the hoisting-rope is as follows: Starting with the end which is fastened to the fall block, after making the necessary number of laps about the sheaves in the carriage and fall block, the rope is conducted to a sheave in the top of the head tower, thence down to the engine drum and around this as many times as may be necessary, thence around a take-up sheave, by means of which a uniform tension is maintained, and back to a point on the rope itself between the carriage and the tail tower, where it terminates, secured by a patent double swivel attachment. The rope thus makes what is practically an endless circuit, to which a short piece is attached, but which in reality is simply the extension of one end, some 200 or 300 feet long that terminates in the fall block, or long enough to allow for the greatest vertical lift, and yet not so long as to overbalance the unloaded fall block and prevent its descending.

TRAVELLING HOIST-CONVEYORS.

In some cases, as for instance the excavating of canals and trenches it is of the utmost importance to have a line that may be easily moved so as to keep in touch with the work. For small canals

and trenches the Hall Patent Hoist-conveyor is very suitable being easily dismantled and re-erected.

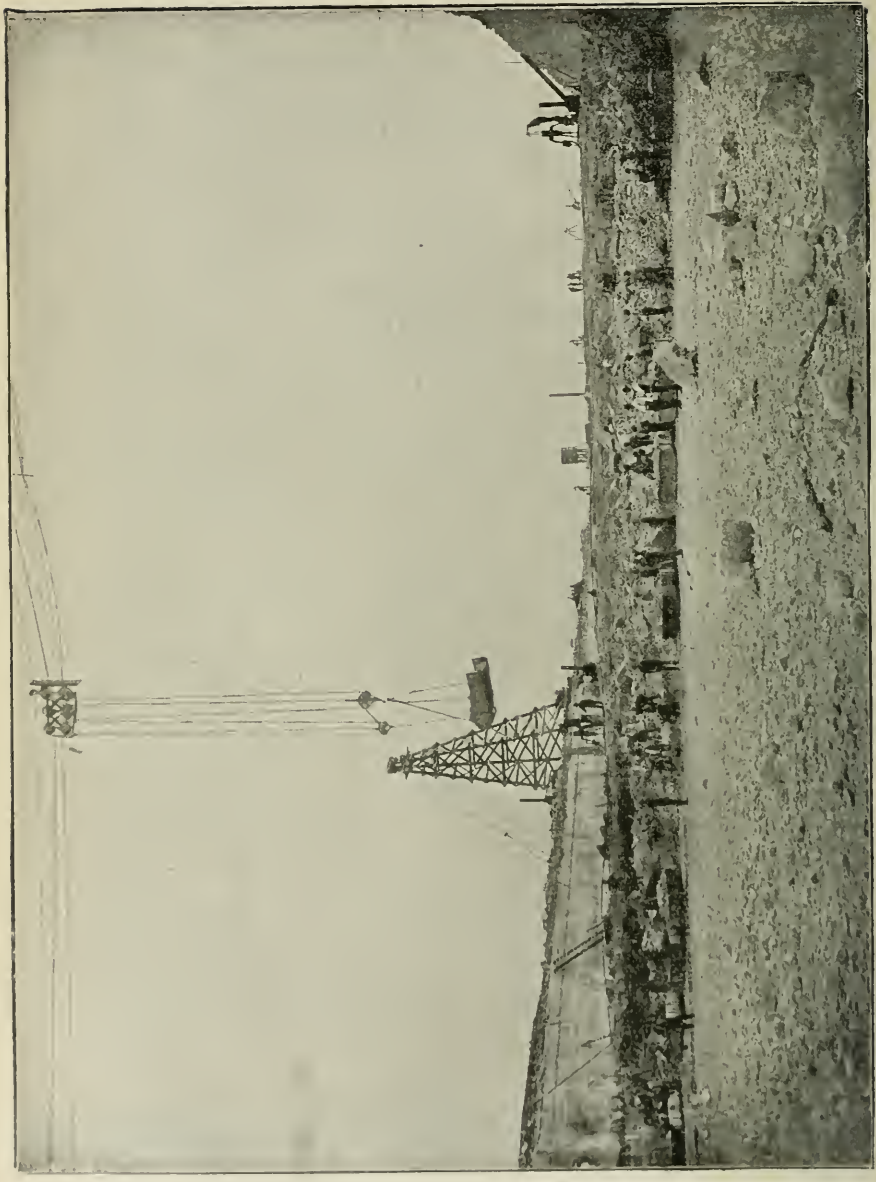
The supports for the stationary cable consist of a mast mounted upon skids on one bank, and a suitable tree or mast on the other, which must be placed far enough from the excavation to leave plenty of room for dumping the spoil. In general the length of the span is 200 feet.

In operating this line three moving ropes are necessary, driven from separate drums. One of these known as the loading rope is fastened to the bail of the bucket after passing through a block, anchored to a "dead man" in the bottom of the canal at a point some distance from the cable line. Another rope called the hoisting rope passes through a block in the carriage to a fastening on the bail of the bucket. The third rope, known as the out-haul rope passes between idler wheels in the hoist carriage to a block at the top of the spoil bank mast, through this to a block attached to the carriage and thence to a link on the bottom of the bucket in the middle of one side.

The bucket is knifed edged and when the loading rope is drawn in, the bucket is dragged horizontally along the bottom until it scrapes itself full. The hoisting rope then lifts the loaded bucket and the out-haul rope takes it to the discharging point. The operation, however, is not so simple as would appear by this description as all three ropes must be worked together, in order to keep the bucket upright while moving and to make it discharge at the proper time. The return also requires very skilled manipulation of the different ropes, especially if it is desired to drop the bucket to some point not directly under the line.

In moving the cableway, the ropes are disconnected, the loading rope being lapped through blocks, one of which is fastened to a "dead man" 50 or 60 feet along the bank, the other to the skids near the foot of the mast. Power is then applied to the winding-up of the loading rope, and the whole rig on the skids moves slowly forward.

A far better style of cableway, where the work to be done justifies its erection, is one in which both towers are well constructed, and run on tracks parallel to the canal. Such a line was used as early as 1888 by Mr. H. H. Carson of Boston in excavating some portions



Loading the Skips, Chicago Canal, Section 8.

of the Boch Bay Park system. Since then the idea seems to have been dropped till the Lidgerwood Co. used the same system in 1890 in making the Chicago drainage canal.

This ropeway as used by the Lidgerwood M'f'g. Co., has a span generally of about 700 feet, the head tower being 93 feet high, and the tail tower 73 feet high. The head tower is the one carrying the engine, and is made higher to add to the size of the spoil bank, as the material is dumped on that side of the canal. The main cable, on which the carriage travels is 2¼ inches diameter steel, and the other ropes are of suitable size to handle a load of 8 tons. To form an anchorage for the cable the moving platform is weighted down with heavy stones, and two iron rods meet above the engine house in a sheave, around which the cable is passed and clamped.

A hauling-rope, hoisting rope, dump line, fall rope carriers, and a button line as already described are used in these lines, a weight box at the foot of the head tower allowing the button rope, to which it is attached, to play up and down a little.

The cars of both head and tail towers are supported by a series of car axles, the wheels of which run on standard gauge tracks. There are two axles under the foot of each post, and at the rear of the car eight axles are so arranged as to give a strong wheel base to support the machinery and ballast, three rails being used to form two tracks, the middle rail being common to each.

The engine is designed to lift 8 tons at a speed of 300 feet per minute, and to convey it along the cable at a speed of 1,000 feet per minute, but with increased steam pressure it works at much higher speeds. The boiler is of the locomotive fire-box type, 70 h.p., and supplies steam for both the cableway engine and the moving engine. There are two drums, one for the endless hauling-rope, the other divided into two parts, receives the main hoisting rope and the dump line. The drums may be worked either together or independently, and are of the same diameter, so that the load may be carried in either direction at a uniform distance from the fixed cable.

The hoisting rope carries the whole weight of the skip, and the dump line comes in slack, but at the same rate of speed. When the spoil bank is reached the dump line is thrown on an increased diameter of the drum, and being thus drawn in at a higher rate of

speed the load is discharged. The dumping takes place while the carriage is in motion, and the engine being immediately reversed, the bucket returns for the next load without the least delay. Special small engines are used for moving, the one on the head car being supplied with steam from the boiler, while on the tail car the engine is run by compressed air from the drill pipe which runs along the canal.

Pulley blocks are attached on both sides of the car to a stationary rope several hundred feet long running parallel to the line of the canal and attached to dead men at each end; and to double ropes attached to the car. A fourth rope is wound through the single blocks on one side, then several times around the drum of the moving engine, and through the blocks on the other side. With this arrangement the towers may be moved in either direction at a speed of 50 feet per minute.

The track is either laid for some distance ahead of the car, or more frequently 15 foot sections, permanently attached to the ties are used, and transferred from one side of the car to the other.

Since the use of travelling cableways by the Lidgerwood Co. has proved so economical and efficient, many other firms have designed similar lines.

The Roebling's Sons Co. make a cableway in which both towers are moved by the same engine that does the hoisting and hauling. The towers may be moved at a high speed up to 400 feet per minute, as there is no danger of one tower running ahead of the other and straining the cable, but this system has the disadvantage of an extra endless rope, spanning the canal, to move the tail tower. An additional shaft in front of the engine is connected to a vertical shaft with bevel gears, on the lower end of which is a winch; around this a steel rope makes two or three turns and is anchored at each end of the track between the rails. The tail tower is fitted in a similar way, the shafts in each tower being connected by a wire rope supported over wheels on top of the towers.

Single line ropeways under special construction have been applied to a great many different classes of transportation, among which we might mention the loading and unloading of vessels, the rescue of passengers from stranded ships, and in recent years the conveyance of passengers to inaccessible or difficult places.

The usual construction for loading vessels is to have the tail tower built out on a pier, and in a slanting position, or with a projecting beam, to allow the buckets to descend to the deck of the boat. The bucket is raised and lowered by the fall rope, and traversed back and forth on the cable by an endless traction rope as in ordinary hoist-conveyors.

On the California and Hawaiian coasts a very neat form of inclined hoist-conveyor is used extensively and is known as a cable chute.

Two or three hundred feet of 2-in. chain is connected at one end to an anchor, and at the other to a similar length of galvanized iron rope. This rope is attached by a light chain to a buoy, and when not in use lies on the bottom. The mast of the vessel forms the lower terminal of the line; and the chain and galvanized iron rope being fastened by a hook and eye coupling to the fixed cable, keeps it at the proper tension and prevents the vessel from being tipped to one side.

In the busy season the track cable is not taken in when a vessel gets through loading, but the ropes are coupled together and cast off. Another vessel coming picks up the ropes, uncouples them, passes the ends between the masts and couples them again; the track cable is then drawn up to a proper distance in the rigging, and the conveyor is ready for operation. Means are provided at the shore landing for imparting the proper tension to the track cable, and also for holding the carriage while raising or lowering, and a latch on the carriage itself prevents the load from falling in transit.

Interesting experiments are now being made by United States warships on the Miller conveyor for coaling ships at sea by the aid of an elevated cable.

The device was proposed in 1893 but has since been modified and improved. It was accepted by the authorities for use during the Spanish war, but was not ready in time.

It is proposed with this device for the warship to take the collier in tow, or the collier to tow the warship, leaving the distance between the ships about 300 feet; this method of securing ships at sea is recognized as being safe. The warship to receive the coal erects a pair of shear poles on its deck, which secured by guys, support a

sheave wheel and a chute to receive the load. The collier is provided with a specially contrived engine, located aft of the foremast, having two winding drums. A steel cable $\frac{3}{4}$ in. diameter leads from one drum to the top of the foremast, over a sheave, thence to the sheave on the warship, back to another sheave on the top of the foremast, thence to the other drum. This engine gives a reciprocating motion to the conveying rope paying out one part under tension.

A carriage of special form conveying bags of coal 700 to 1,000 lbs. is used, and is provided with wheels which roll on the lower part of the conveying cable, and grip on the upper part of the cable. This arrangement does away with a stationary cable, the returning rope taking its place by supporting part of the load.

During the transit of the load an elevator car descends to the deck of the collier and is loaded with bags of coal suspended from a bale, and elevated again to stops on the guides, so that a hook on the returning carriage engages with the bale supporting the coal bags, and the direction of the ropes being reversed the carriage makes a trip back again to the warship.

The speed of conveying is about 1,000 feet per minute, consequently the load will be taken from the collier and deposited in the warship in about twenty seconds. The total tension on the rope will never exceed say 8,000 lbs.; furthermore should the ships pull away from each other and the tow-line part, the only effect will be to unwind the rope from one of the drums, its end falling into the water, whereupon the other drum will wind it up and recover the carriage.

CABLEWAYS FOR PASSENGER SERVICE.

Cableways used exclusively for passenger traffic are as yet very rare, but many lines installed for the transporting of material are used incidentally for this purpose. A ropeway on the "Bleichert" system over the Chilkoot Pass in Alaska is a notable instance of a ropeway used in this capacity, for during the summer months many miners on their way to and from the Klondike make use of it to traverse this difficult piece of country.

Probably the only line of any considerable length in use at the present time, constructed solely for the carriage of passengers is situated in Hong Kong in connection with a large sugar works, in

which a number of European workmen are employed, and to secure freedom from fever these men are transported at the end of their day's work to a sanatorium at a high level above the sea. The carrier is arranged for the accommodation of six men at a time, the speed of the ropeway being eight miles per hour.

Several years ago a passenger line was erected at Knoxville, Tennessee, and had this proved a success it is probable that it would have been soon followed by many similar lines all over the country. The ropeway consisted of two $1\frac{3}{8}$ in. wire cables spanning the Tennessee river a distance of 1,060 feet, and anchored on the bluffs on either side which are 350 feet and 230 feet above the water. The cables combined had a breaking strength of 240,000 lbs. The car was 20 feet long by 6 feet wide and $6\frac{1}{2}$ feet high weighing empty 1,200 lbs., and having a seating capacity of sixteen passengers. Automatic brakes were provided in case the propelling cable should break or run slack.

The trip down was made in about half a minute and the return in three and a half minutes. The fare being five cents.

The line was only operated for the part of one season, when the breaking of the moving cable caused a serious accident, which resulted in the killing of one of the passengers by one end of the broken cable striking him on the head. The car came to rest at a point some forty or fifty feet above the river and the passengers were rescued by a steamboat run under the car.

About the same time a similar ropeway was designed to cross the Ohio river at Wheeling, West Virginia, to Wheeling Island, a distance of 3,000 feet. It was to have two cars carrying fifty people each, and make the trip across at the rate of 1,000 feet per minute.

This line was never erected owing probably to the failure of the line at Knoxville which seriously involved the promoters financially.

CABLE SHOOTS.

There is still another system of ropeway in common use called a "shoot," having one fixed rope placed on an incline, on which carriages are allowed to run down uncontrolled, one at a time. This system is of a simple nature, and used for the transport of undamageable goods. The carriages have one or two wheels and carry loads from 100 to 400 lbs. At the lower end brushwood or other convenient

means are provided to absorb the force produced by the running load when it arrives at the lower terminal. This can be considerably lessened by regulating the sag of the rope, where the section of ground will admit, so as to reduce the speed of the runner with its load as it approaches the lower terminal.

Spans can be made without support up to 7,000 feet, and all that is required for fixing the rope is a good anchorage at the upper end another with a tightening gear at the lower end.

Ropes for this purpose up to 3,500 feet span are made in the form of a strand, above this in order to obtain the necessary strength with a moderate size of wire, the ropes consist of several strands formed each of a number of wires.

The runners have wheels of small diameter and are made as light as possible, in order that after 50 or 100 loads have been delivered, the empty ones may be carried up to the upper end for a further delivery of material.

The applications of this system are too numerous to mention; probably many hundreds of miles are in operation, being used largely for the transport of firewood, coffee, and like materials, and is found where practicable to be efficient, economical, and speedy.

WIRE ROPES.

Before concluding this treatise it will be of advantage to say a few words about the construction and use of wire rope, for on it depends the whole working of the line.

In America the common practice is to construct the wire cables similarly to the hemp ropes, strands being first woven from the small wires and these, again woven together about a hemp or wire center, but in an opposite direction from the original wires.

Ordinary wire rope is composed of six strands each containing seven, twelve, or nineteen wires laid up about a hemp or wire center.

"Nineteen wire" rope with hemp center, having great pliability is best suited for running ropes on cable railways, while "seven wire" and "twelve wire" ropes being stiffer and less flexible are better adapted for guys and stationary ropes, and when employed for this purpose are galvanized. For transmission of power "seven wire" rope is generally preferred, as owing to the larger size of the component wires, a greater wearing surface is offered.

To overcome this undue wear the English custom is to lay the strands about the hemp center in the same direction as the individual wires, being just the opposite direction to the strands in ordinary ropes. This system of winding is also used to some extent in America, being known as the "Lang" or "Albert" and sometimes the "Universal" lay. Ropes wound in this way are more flexible than ropes of the same diameter and composed of the same number of wires laid in the ordinary way, and owing to the fact that the wires are laid more axially in the rope, longer surfaces of the wires are exposed to wear, and the endurance of the wire is thereby increased.

To present a maximum wearing surface, the Trenton Iron Co. manufacture a special kind of rope, which they call a "locked wire" cable, the outer wires being of such a shape that they interlock with each other, presenting a smooth surface.

These ropes have wire cores and on this account are somewhat stiffer than ordinary cables of the same size, but being much stronger a smaller rope of this design can be used for the same work, and for equal strength it is more flexible.

A cable having a similar smooth surface is made by the California Wire Co. for track cables. It consists of nineteen heavy wires, seven of which form a core, the other twelve alternately a round and a triangular wire are wrapped around this core.

Wire rope is usually shipped on reels holding several thousand feet, but where any part of the line is inaccessible to waggons, the rope and the rest of the machinery must be packed so that it can be loaded on mules. Each animal carries about 250 lbs., including a piece of slack rope about twenty feet long, connecting its load to the next one in the rear. This piece is usually held up by a native, so that it will not drag on the ground.

Wire rope must not be coiled or uncoiled like hemp rope. When it is wound upon a reel, the reel should revolve on a spindle while the rope is paid off; when laid up in a coil not on a reel, the coil should be rolled on the ground like a wheel, and the rope paid off in that manner, so that there will be no danger of untwisting or kinking.

To preserve the rope and prevent undue wear it should be covered thoroughly with raw linseed oil, or with a paint made of equal parts of linseed oil and spanish brown, or lamp black.

The drums and sheaves along the line should be as large as possible, for the larger the sheaves the less bending will occur in the cable and consequently the less wear. However every maker of wire rope supplies a table of the minimum diameters of sheaves to be used with every style of cable for a maximum safe working tension and the size of the sheaves depends largely on these values.

THE PROBLEM OF SPEED REGULATION IN PLANTS DRIVEN BY WATER POWER.

W. A. Hare, Grad. S. P. S.

Among the many problems which the generation of power from water falls has brought to the attention of the engineer, the question of speed regulation, under the complex conditions which surround a modern water power plant, may be considered as being one of the most important.

The present demands for constant speed, brought about, to a great extent, by the widespread adoption of water falls as a motive power in operating electrical machinery, have only lately been complied with.

It was necessary, before success was assured, to determine what influence the design of different parts of the plant had on the regulation; and also to produce a governor which would retain a constant speed under the conditions of favorable design.

It is the intention of the writer in this paper to show how, by correct design, many of these influences which are detrimental to close regulation, can be considerably reduced. In nearly all this work, there is a large element of uncertainty, arising from the nature of the problem, in which experience is the only teacher; still in many cases theory will be of considerable assistance in preparing the design.

VARIABLE LOADS.

With the adoption of electrical transmission as a means of operating power machinery at a distance, have been introduced those extremely variable loads which make regulation so difficult.

The loads on electrical lighting circuits do not vary so suddenly as those of electric railway or power circuits, and therefore it is much easier to control the speed of the dynamos. In the case of an electric railway, if a number of cars are thrown off at once, the speed of the

dynamo would immediately increase, and as in most machines the voltage is proportional to the speed, it will be subject to those variations which, to say the least, are extremely undesirable. To control the speed of a turbine, when the load is varying from half to full load and vice versa, is a feat which will be found difficult with the best type of governor.

When many dynamos are driven from the same shaft, there is not the same danger of a sudden drop in the total load on the wheels, as the several fluctuations in the separate circuits tend to counteract each other. If there are only 2 or 3 machines, there is the remote possibility of a conjunction of a drop in all loads; but as this case is not at all likely to occur it would not be necessary to consider this case in the general problems of regulation.

Many operators of electric railway plants driven by water power, have considered this method of driving too risky and dangerous to be successful. This is simply because the design of the plant was such that it was almost impossible to secure the degree of regulation required with the existing load variations.

In all plants where a number of turbines are supplied from the same pipe or flume, and where the fluctuations of load on each individual turbine are distinct from those of any other in the set, the resulting changes of velocity in the supply pipe, which is approximately the algebraic sum of all the momentary changes in each of the turbines, will be very much less than if each wheel were supplied from its own pipe. In installations of this kind, water hammer is not so formidable, and in many plants is almost negligible. The same effect is reached, if we have all the loads of the separate turbines taken from one common shaft, to which each turbine is connected, by belts or gearing. By this means, a load variation, which would be considerable if it came all on one wheel, will not influence the speed to any extent when it occurs as a variation of the common load. If we were to take out the line of turbines, and replace them by one or two wheels of large power, the variations of the load would have the same influence as when all the wheels were coupled.

We then can reduce the effect of heavy load variations by employing large units, or by coupling the small ones. In either case the load variations, by being distributed over the whole plant, do not have so much effect on the speed, and also, the velocity of the water in the

flume is not changed materially when the governor is put into action to compensate for them.

There are a large number of plants now in successful operation, in which the regulation is as close as could be effected by a steam engine. This degree of success has only been brought about by a close study of the problem, not only on the part of the designing engineer, but also on the part of the inventors and builders of the water wheel governors.

WATER HAMMER.

The exact influence that the length of the supply pipe, and the height of the fall, exerts on the problem of successful regulation, does not seem to be fully understood, even by many practicing engineers.

What was originally disregarded as of no consequence in designing an installation, on account of either low heads, or that constant speed was not absolutely necessary, now becomes a live problem, which must be solved before successful regulation can be secured.

The peculiar action of "water hammer," or "water ram," as it is sometimes called, is one that calls for our best attention when considering regulation. If we have a long pipe, discharging at a given rate, and attempt to throttle the water at the orifice, we will find that before we can check the flow to the value corresponding to the new area of the orifice, we must check the velocity of the water throughout the entire pipe; and as will be shown by the following equation, this represents a considerable change in the kinetic energy. The kinetic energy in the pipe line is represented by the formula:—

$$K=\tfrac{1}{2}\frac{W}{g}v^2 \qquad (1)$$

Where K is the total kinetic energy present in the pipe line in ft. pds. per second.

W is the total weight of water in the pipe line, in lbs.

v is the velocity of the water in the pipe line, in ft. per second.

If we change the velocity in the pipe from v to v_1, the kinetic energy must change also.

We have $K=\tfrac{1}{2}\frac{W}{g}v^2$

and $K_1=\tfrac{1}{2}\frac{W}{g}v_1^2$.

Now let v_1 be less than v then by subtracting we get,

$$K - K_1 = \frac{W}{2g}(v^2 - v_1^2) \quad \ldots\ldots (2)$$

The difference in the kinetic energy must be expended in some manner, before the velocity can be reduced to v_1. It will be found that if the valve is partly closed, the pressure at the lower end will rise suddenly, and if the valve is closed quickly, any great proportion of its travel, and no means are provided for the escape of the water, the pressure will rise high enough to perhaps burst the pipe.

From the standpoint of regulation, this effect of water hammer is very objectionable, so much so, as to prevent the use of governing systems which change the power supply by throttling the orifice, in cases where the effects of water hammer cannot be sufficiently reduced. When the regulation is effected by deflecting the jet, which acts on the wheel, the velocity in the supply pipe does not change with the variations in the load, and therefore no water hammer effect is created. This method can only be used with wheels of the Pelton type, and therefore does not come into the present discussion. With all types of reaction turbines, regulation is secured by varying the quantity of water passing through the wheel per second, and as there is no alternative open to us, we must consider the effect that water hammer has on the regulation; and see if there are not means by which it can be reduced, if not removed altogether.

Let us trace the course of events which take place when a turbine, operating at the end of a long flume, is regulated by means of a governor. We will suppose that the plant is running at a constant speed, when an increase in the load occurs. As soon as the speed begins to change, the governor is put into action, and attempts to connect the irregularity, by partly closing the gates. This action on the part of the governor will necessarily take some time, but even then, the velocity of the water in the supply pipe will be checked much too soon to prevent water hammer. The effect produced is a sudden rise in the pressure of the water near the wheel, which increases the velocity of the water passing through it. It is quite possible, then, that even if the gates be partially closed, the wheel may receive more power than it did before the gates were moved. This effect, though lasting only for a very short time, is sometimes in action

long enough to allow the speed to be accelerated, and for the governor to close the gates still further. During this time, the kinetic energy represented by formula (2) has, to a great extent, been expended in giving velocity to the issuing water, and we now find the velocity of the water in the wheel not far above normal. In this double movement, the governor has closed the gates too far, and as soon as the velocity falls back to normal, the power supplied to the wheel will be found to be insufficient for the demand. The speed consequently falls, thus energizing the governor, which begins to open the gates again. The opposite effect is now produced in the supply pipe, which still further complicates matters.

We have found that a change in the velocity of the water in the pipe, necessitated a considerable change in the kinetic energy in the pipe line. When the gates were closed, a large amount of energy had to be disposed of, in some way, before the velocity could be reduced. Similarly, when a higher velocity is required, there must be an increase in the kinetic energy in the pipe, before the velocity can increase. All the energy in the pipe is obtained from the action of gravity on it, and in the case of long pipes, as will be shown later, there is a considerable duration of time required before the velocity can be brought back to normal. In the case under discussion, the governor had opened the gates, but as this was followed by an increase of power, in fact by an actual diminution, the gates are opened still wider. The gates are now opened too far, and it is not long before the speed is increased which again puts the governor into action, and the same fluctuations are repeated.

We can easily see that with such disturbing influences, regulation, except for very slight variations of load, would be an impossibility if we had no method of reducing or preventing this action.

DRAFT TUBES.

In the design of the draft tubes, these same influences against good regulation must be considered, together with some new ones. It can easily be seen, from what has been said, that theoretically, the draft tube should be as short as possible. We cannot, however, change the diameter, very much, unless we make it slightly conical, with the smaller diameter at the wheel. This design is preferable, not only

on account of regulation, but also, because it adds to the general efficiency of the installation.

The maximum length for any draft tube is theoretically about 34 feet, or the height of the water barometer; but for various reasons it is never made more than 25 feet, unless other considerations outweighed the ones under discussion.

If we have a draft tube 34 feet long, the pressure outside, at the top, will be approximately 14.7 lbs. per square inch greater than that inside, and for this reason we can hardly expect them to remain perfectly air tight. Any leakage of air at once destroys the vacuum, more or less, and when this occurs we have losses of head and efficiency which make our problem extremely difficult.

In all draft tubes, the water is held in position by the pressure of the atmosphere on the surface of the tail race. The pressure at the top of the column will always be less than atmospheric, depending principally on the length of the draft tube. When the plant is running normally, this pressure will remain fairly constant; but will vary with each change in the gate opening. If the quantity of water flowing per second is changed, by a movement of the gate, the kinetic energy of the column of water in the draft tube must necessarily change also, and can be expressed by formula (2). When the gate movements are gradual, the above change will not affect the regulation; but, on the other hand, if the gate is closed, suddenly, the velocity in the draft tube will not be changed as quickly as the gate movement would call for, and, as a result, the column will part at the top, and drop in the draft tube.

The change of kinetic energy represented by formula (2) must be expended in some way before the velocity can be reduced. Under normal conditions, the pressure on the top of the column, together with the pressure due to the height of the water, balances the atmospheric pressure; but when the column falls, these pressures are reduced. This creates an upward pressure at the bottom of the draft tube, which absorbs the kinetic energy, and reduces the velocity. When this has been done, the level of the water will be too low, and therefore the water will rise suddenly, and, if the disturbance has been very sudden, may strike the wheel with considerable violence. Apart from the liability to accident from this cause, it is evident that

the effect of this swaying column must be very detrimental to regulation, since the head acting on the wheel, and consequently the power supplied, will vary with these fluctuations. If this occurs a few times, in all probability the draft tube will leak air, as the seams will have been started by the force of the returning water. With the introduction of air in the draft tube the trouble is more serious, as the continual supply of air through the leak, prevents the formation of the proper degree of vacuum. The result is, that there exists a partial and constantly varying vacuum, which causes the column to permanently break at the top. It is now suspended in the draft tube, swaying up and down with every slight change in the load. This produces a corresponding pulsation of the working head on the turbine, which would by itself almost effectually prevent any success in regulation.

If we make the draft tube short, we reduce the W in formula (2), and consequently reduce all these tendencies. This should always be done as far as possible, consistent with the demands and purpose of the installation.

STAND PIPES.

In many designs of water power installations, the regulation is in no small measure due to the stand pipe on the supply pipe. Stand pipes are of special value in plants; firstly, which have comparatively low heads, say under 40 feet; secondly, in which the fluctations of the load are violent and of very short duration, as for instance in an electric railway power-house; and thirdly, in countries where the winter is not too severe.

It is not, in electric plants, of as much importance that a complete change from friction load to full load should be attended with a moderate fall in speed, as that large fluctuations of the load, which occur at short intervals, should not change the speed to any considerable extent: and it is in cases such as these that we get the most value from the use of stand pipes.

The stand pipe is located at the lower end of the flume or supply pipe, as near to the penstock as possible. It should be designed to be of sufficient diameter, so that the static pressure at the wheel will not vary very much for a given change in the velocity of the water in the flume. The top of the stand pipe should extend a little above the level of the water in the pond or forbay, and it is for this reason that it is

not applicable for high heads. Practice determines that stand pipes should be of the greatest diameter possible, and not to extend further above the level of the water in the forbay than to prevent water running over the top when the plant is shut down. The top should be turned over and an escape pipe put up to allow the overflow to run off.

In a plant equipped with a stand pipe, should a considerable proportion of the load go off; as for instance that caused by the throwing of a circuit breaker in an electric plant, the governor immediately closes the gates to the correct position for the new demand. The velocity of the water in the flume being thus checked, the water ram effect is expended in forcing water up the stand pipe and over the top. The static head on the wheel, and the corresponding pressure in the wheel case, can never be greater than that due to the column of water in the stand pipe, which as before mentioned, is only a short distance higher than the water in the forbay. The water ram effects are therefore disposed of effectually, because the velocity was not checked as quickly as if there were no stand pipe used, and therefore less water ram was created.

Should the load return to its original value again, the demand for water at the wheel will have its effect in lowering the pressure, and consequently the level of the water in the stand pipe will fall a corresponding amount. This drop in the level of the water means that the stand pipe has given up a certain amount of energy to the supply pipe, and thus tends to retain a more constant pressure over the wheel than otherwise.

It is therefore evident that the stand pipe, if it is to be capable of assisting materially in maintaining a fairly constant pressure over the wheel, cannot be much higher than the hydraulic grade line at that point, if the pressure is to be kept down to normal, and on the other hand, will have no range of action, if not made higher than this. The only course open to us, then, is to increase the area of the pipe at the top, so that a large quantity of water can pass up or down the pipe, without there being too much variation in the level of the water. We can, in this way, compensate, to some extent between the two demands to be made on it, which seems to determine the lines along which the design should be made.

If the flume or supply pipe is long, the water hammer effects will be proportionately great. To diminish these effects by means of a stand pipe we will require one of sufficient area and height to meet the conditions, which will add considerably to the expense of the installation, not only for the pipe itself, but for the foundations that will be required to carry the weight of the pipe and contained water.

In countries like ours, where the temperature in winter falls to many degrees of frost, there is another element introduced in the problem, not encountered in countries farther south. If the surface of the water in the stand pipe should freeze over at night when the plant is shut down, the whole effect is destroyed, as the water is not now free to rise and fall with the pressure. In any case, in cold weather, even if the stand pipe was in operation, the ice on the sides would gradually accumulate until the pipe was completely closed, which would render it absolutely useless for regulating purposes.

Apart from these disadvantages, the stand pipe is of undoubted value in maintaining a constant head on the wheels, and so far seems to offer more advantages in favor of their adoption than otherwise.

AIR CHAMBERS.

When the head is too high to admit of the use of stand pipes, other means must be employed to reduce the effects of water hammer. The most natural step from the open stand pipe, in the case of high heads is to seal up the top, and allow the rising water to compress the air contained in the pipe. This idea has been enlarged on and as a result we have the present air chamber.

The air chamber, at best, is not of much use as an aid to regulation, as the pressure in it will rise and fall almost the same as it would in a stand pipe which was considerably higher than the static water level. When stand pipes are installed, it has been pointed out that they are made so that on an increase in pressure the water will rise and overflow. This prevents any degree of head higher than the top of the stand pipe. With air chambers, however, there is no limit to the pressure, so we still have those fluctuations of head which are so detrimental to regulation.

The chief use to which air chambers are put, is as a safeguard against water hammer, and when properly designed for this purpose they introduce a considerable factor of safety. It is evident that to absorb the energy of the moving column of water, the air chambers should be of ample size, to be of any service. They are sometimes installed on a pipe line and no further notice taken of them. This is a mistake, as water under pressure absorbs air, and an air chamber which at first would answer the purpose for which it was designed, would, in the course of time, be gradually filled with water, and become worse than useless. If a water glass, or a set of try cocks, be placed on the side, the level of the water can be readily ascertained. To replace the air which has been absorbed, an air pump should be used. If air-chambers are not pumped full of air, they will only be perhaps one-half full, when the full pressure is on, and the full effect one would expect from the size of the chamber is not obtained.

RELIEF VALVES.

Another device which is used to some extent to offset the influence of water hammer, is the relief valve.

In its simplest form, it is a spring balanced valve, placed on the supply pipe, which opens when the pressure in the pipe has reached a certain value, and by allowing the escape of the water, tends to prevent the pressure from rising much above this point. As soon as the pressure has fallen, the valve closes automatically. If designed on the right principles, and of ample size, these valves may be of considerable value in preventing great increases of pressure; but if not, they are very little good. One fault usually made, is that they are altogether too small for the work required of them, and consequently fail in their duty.

A combination of the air chamber and the relief valve is meeting with some success, and evidently contains some good features. The air chamber is placed between the valve and the supply pipe, and is supposed to ease the discharge from the relief valve when it experiences a sudden rise in pressure.

RELUCTANCE OR LAG.

We have shown in the preceding articles, some of the effects produced when the velocity in the supply pipe is checked by closing

the turbine gates. These effects, though being extremely objectionable from the standpoint of regulation, can, with good design, and by taking proper precautions, be considerably reduced, if not entirely eliminated. If this were the only problem before us, the difficulty encountered in securing close regulation would not be so great. As it is we have another very important effect produced when the gates are opened again. If we have a plant in which the supply pipe is short and well designed, operating under a moderately low head, this does not become at all a serious matter, but in cases where the pipe is long, and poorly designed, we find that it is extremely difficult to secure good regulation.

In all turbine plants, regulation is effected by changing the quantity of water passing through the wheel per second, and if this could be done while the pressure was kept constant, we would have no difficulty in securing good results under a wide range of conditions. It always happens, however, that no matter how well the plant is designed, the pressure at the wheel will vary somewhat with each new movement of the gates, thus introducing another variable quantity which influences the power delivered to the wheel, and consequently the regulation.

It should be the aim of every designer to reduce as much as possible the variations of pressure which occur at the wheel when the gate is moved, as by doing so one of the greatest difficulties in the way of regulation will be removed. We will now consider some of the chief agencies which cause a change in pressure at the wheel, when the gate opening is varied to suit the load requirements.

Suppose we have a supply pipe delivering a certain quantity of water per second, with the gate opening one-half its maximum. In this case the velocity of the water as it issues from the orifice is very close to its theoretical value, and will not change from this if other conditions remain constant. This is called the velocity for steady flow.

Under these conditions, there is equilibrium in the pipe. The forces acting on the water in the pipe line, expend themselves in giving to the issuing water its velocity. If now the gate be opened to its fullest extent, the equilibrium is destroyed, because the back pressure at the orifice has been reduced. The first effect which occurs when the gate is opened, is a considerable decrease in the issuing

velocity at the orifice, for as the velocity of the water in the supply-pipe was not changed as quickly as the gate opening, the issuing velocity must become less in order that the same quantity per second be discharged. The velocity of the water in the supply pipe, will now increase until equilibrium has been once more established, which will be brought about by the velocity of the issuing water coming back to its former value. It is evident that the velocity at the orifice, after being reduced, will require some time before it can arrive at its normal value, corresponding to steady flow, and as a reduction of the velocity means a reduction of the power supplied to the wheel, we see that this *time* has considerable influence in the regulation. In order that we may determine the time required for the velocity to reach the steady conditions, we will consider the problem in its simplest form.

Let us suppose a pipe of a certain length l, and let the difference in level between the two ends be H. The maximum velocity at the lower end of the pipe when it is running full, and under conditions of steady flow, will be, if we neglect all frictional resistances, the theoretical value represented by the equation:

$$V = \sqrt{2gH}.$$

Let v be any proportion of this maximum value. Let us suppose that the pipe is full of water, and with the lower end closed. If now the gate at the lower end be instantly opened, the time that will elapse before the velocity of the issuing water reaches the value v, will be represented by the equation:

$$t = \frac{l}{\sqrt{2gH}} \log_e \frac{\sqrt{2gH} + v}{\sqrt{2gH} - v} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Where t is the time required for the water in the supply pipe to reach the velocity of steady flow, from rest; l is the length of the supply pipe in feet; H is the head of water acting on the wheel; and v is any velocity at the orifice between zero, and its maximum value V.

If we let $v = V = \sqrt{2gH}$, t becomes infinity. This is the theoretical time required under these conditions, and is of course useless to us in this form. If, however, we let $v = .95\ V$, we get a finite value for t which is not very far from what we would expect in an actual case.

In Fig. 1 are shown a number of curves which have been plotted from the above equation, in which different values for the maximum velocity have been taken. In all cases l has been taken as 100 feet.

In practice we cannot take values calculated from this equation as being true as the suppositions are somewhat limited. Still they serve to show the general theory under which the water is moving.

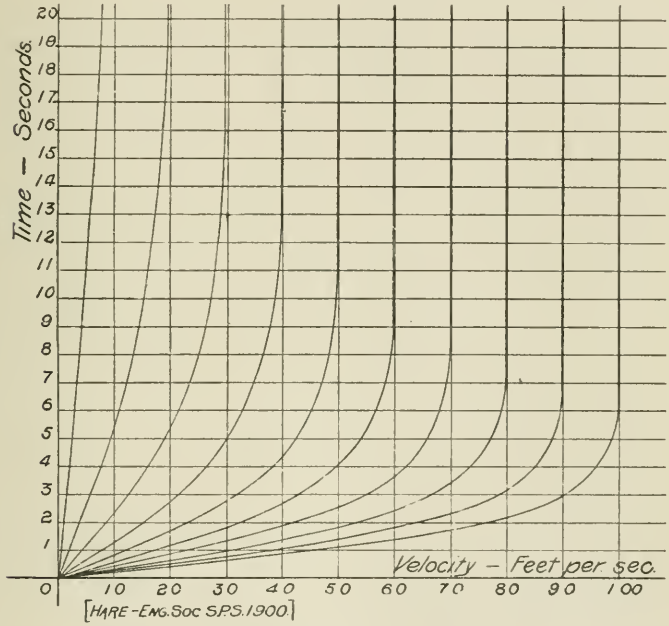


FIG. 1.—TIME—VELOCITY CURVES, FOR SUPPLY PIPES.

If we consider the effect of the gate opening, as compared with the cross sectional area of the supply pipe, we find that the equation is slightly different. If we let A_1 represent the area of the supply pipe, and A_2 the area of the gate opening, the equation becomes:—

$$t = \frac{l\left(\frac{A_2}{A_1}\right)}{\sqrt{2gH}} \log_e \frac{\sqrt{2gH}+v}{\sqrt{2gH}-v} \quad \ldots\ldots(4)$$

As v represents the velocity of the water at the orifice, the last part of this expression gives the same value as formerly; but as $\left(\frac{A_2}{A_1}\right)$ is

always less than unity, the value given by the first part of this expression is directly proportional to the value $\left(\frac{A_2}{A_1}\right)$, and therefore the time t required is much less than when found by equation (3).

We see by this that the time can be reduced by making A_1 large as compared with A_2; that is, by making the area of the supply pipe large as compared with the maximum value of the gate opening.

Suppose we wish to find the time required for the velocity in a pipe 250 feet long, installed under a head of 99.5 feet, to reach the condition of steady flow, from rest. In Fig. 1 we find that the time for the water in a pipe 100 feet long to reach the velocity of 80 feet per second,—which is the theoretical maximum—is about 7.2 seconds. Now as the time is proportional to the length of the pipe, the time in our case will be $7.2 \times 2.5 = 18$ seconds. In no practical case would these conditions apply, but if we now assume values for A_1 and A_2 and introduce them in equation (4), we will find the time considerably reduced. Let $\frac{A_2}{A_1} = \frac{1}{9}$, which is a value taken from actual practice, the time will then be $\frac{1}{9} \times 18$ seconds $= 2$ seconds, which is a fair approximation to the actual case.

As friction has been omitted in this work, the time will be somewhat greater than that calculated.

Perhaps we are not so much interested in the time required for the water to reach its maximum velocity, as we are in the time elapsing before the full power of the wheel could be obtained from the water in the supply pipe, after the full load was thrown on.

Suppose we have a wheel running at its normal speed under friction load only,—which would be with about 6 per cent. gate opening — and the full load were instantly thrown on. The gates are rapidly opened by the action of the governor; but as we have already shown, the water in the pipe line requires some time to reach the condition of steady flow again, and therefore the power of the wheel will not be developed for some seconds after the movement of the gate.

Although we can tell with fair accuracy the velocity at the wheel at any time, we cannot find the pressures. If we suppose that the

pressure in the wheel guides is atmospheric, we may express the energy being delivered to the wheel per second, by the equation—

$$P = W \frac{v^2}{2g} \qquad (5)$$

Where W is the weight of water passed per second, and v is the velocity of the water in the guide passages; which in this case will be very close to the theoretical maximum.

Under these conditions it would be easy to plot a curve showing the energy being delivered per second for each value of v as it increases to its maximum; but even then, we would not have the power of the wheel, unless the wheel was running at the correct speed for entry without shock.

Unless a turbine is running at or near its normal speed, the energy of the water is not absorbed entirely, but expends itself in other ways. For instance: if the wheel is running too slow for entry without shock, the energy is partly expended on the wheel, and partly in giving a high velocity to the water at the off-flow; or if running too fast the energy of the water is not utilized to its fullest extent. In either case a knowledge of the power of the issuing stream would only give us a rough approximation to the energy being absorbed by the wheel.

There is another disturbing element, which, with large movements of the gate would make our work more difficult and that is the efficiency of the wheel at part gate. Most modern turbines are designed to give their maximum efficiency at seven-eighths gate so as to allow a margin of gate movement from about three-fourths to full, without much variation in the efficiency. Below three-fourths gate the efficiency drops rapidly, and any calculations made on the supposition of uniform efficiency would be very rough approximations at best.

The above equation will only be true, when the pressure in the guides is atmospheric, and also when the wheel is running at the proper speed for entry without shock. As in any practical case, these conditions are not likely to be met with, it is useless to try to express the power being supplied to the wheel by this equation as is sometimes attempted.

STORED ENERGY.

In steam engine design, owing to the intermittent manner in which the power is supplied to the crank shaft, and to the variations of the load on the engine, flywheels are required to equalize the effects resulting from this variation of demand and supply. For the same reasons flywheels are necessary in water power plants where these conditions apply; but in the case of water powers, we meet with various other difficulties which make it necessary to provide this capacity for power storage.

1st. The principal reason for power storage in any case, is to provide a reserve of energy between the *demand* for a change in the power, and the *supply* from the source of energy. It is evident that if we could supply the new demand for power exactly as soon as it was required, the speed would not show any fluctuation, and there would not be any power storage needed. This is impossible, as by our system of governors, the speed has to change before the governor can act. As in the ideal case, there is no time lost between the demand and the supply, designers of governors should aim to lose as little time as possible in getting the governor to work. All time lost here will increase the amount of power storage required. This shows the influence of the sensitiveness of the governor on the power storage. We may however almost neglect this loss, as in all of the good governors now on the market the sensitiveness is most satisfactory.

2nd. The rigging of the gate, if not constructed in a substantial manner, will introduce a time loss between the movement of the governor and that of the gate. If the shafts are too light, we have torsional effects, and the gate movement does not correspond to the motion of the governor. With good design this loss may be neglected.

3rd. The gates to be moved in regulating a water power plant, being in many cases very heavy, cannot be opened and closed as easily and quickly as those of a steam engine for instance; and as the changes in the power supplied cannot be quicker than the operation of the gates, it is evident that the power storage, sufficient to retain the speed within certain limits, until the gates do operate, must be much greater than in ordinary cases of quick moving valves.

4th. It has already been shown that when the gates of a water wheel are opened quickly, the ultimate velocity is not attained until some time has elapsed; the amount of time lost in this way depending on the design of the supply pipe, etc. When a sudden change in the load occurs, and it is required that the variation of the speed must not go beyond a certain limit in a certain time, and also as it requires time to effect a change in the position of the gates, and also in the velocity of the water in the supply pipe; it is evident, that to retain the variations of speed within the required limits, before the new movement of the gates can be completed, we must have some means of storing power, so that it may be given up to the system on an increase of load and absorbed by the system when a decrease occurs.

For instance let us consider the case of a wheel driving a dynamo, and having on the same shaft a flywheel of suitable design. Suppose the dynamo is only operating at half its output, and everything is normal at this load. The switch is thrown on, increasing the output from half to full load. The governor instantly begins to open the gates to provide more power, but gravity will not act on the water in the supply pipe as quickly as is desired. If the change in the load was, say 50 h.p., and 3 seconds must elapse before the water in the flume has reached its full velocity, then it is evident that the speed would rapidly fall considerably below normal, if no other source of energy were present. The flywheel, however, contains in itself a certain amount of energy, and as soon as the new load is thrown on, and the speed begins to fall, it gives out energy to the revolving parts sufficient to tide over the intervening time, thereby tending to retain the speed at its normal rate. The energy contained in a revolving flywheel is proportional to the square of its anguar velocity; so that in slowing down it must give up the amount of energy represented by the change of speed. Should the change in the above example be of the opposite nature, i.e., should 50 h.p. be instantly thrown off, the governor will begin to close the gates, which will require some time, according to the rate at which the water hammer can be disposed of. As the system is now running under an accelerating torque of 50 h.p., the speed will rapidly increase. The flywheel cannot be revolved at a higher velocity, without there having been spent on it an amount of energy corresponding to the increase in speed; and therefore by absorbing a large amount of this energy, the speed is

kept within limits, until the movement of the governor has been completed, and the power supplied from the flowing water reduced to its new value, corresponditing to the condition of uniform flow.

With good design in the wheel, gates, supply pipe, etc., the necessity for such power storage will be reduced considerably. In many cases where the designs have been prepared, apparently without any regard to the requirements of a plant for good regulation; fairly good results have been obtained by the adoption of flywheels, of a more or less ponderous nature, bringing with them difficulties in support, in bearings, and in balance, which are usually a source of trouble and expense. In many cases, it is an alternative between the installation of a flywheel, and the reconstruction of other parts of the plant. The cheaper method should be adopted if the results expected are equal.

It is frequently found that in cases where turbines are installed under medium heads in open flumes, that no flywheel is necessary. This is because the "reluctance" of the water is reduced to a minimum, allowing a sensitive governor to operate to advantage, and very little time is lost between demand and supply.

It must not be inferred, that because there is no flywheel, that therefore there is no power storage; as it must occur, to a more or less extent, in all moving machinery. In this case, the flywheel effect is produced by the wheels and connected machinery; especially if the plant is an electric one, where the turbine is directly connected to the large generators, as the armatures or inductors would serve the same purpose.

When variations in the load occur slowly, the governor can move the gates quickly enough to take care of the speed, without there being much power storage. It is with the violent fluctuations of load that the true value of the storage capacity is brought out.

In the case of an electric railway or lighting plant, violent changes in the load, are more apt to occur as decreases, than as increases. A short circuit on the leads may throw the circuit-breaker, when any proportion of the full load will be instantly thrown off. The power storage should be sufficient to retain the speed below a dangerous limit until the governor has had time to close the gates, which action, in no case, can be done quicker than the water hammer effects can be absorbed; and as with such changes of load the gate

movement will be proportionately great, the closing will take some time. When the load is thrown on, it is usually done by the attendants, and the change is not likely to be as severe.

Power storage has considerable value in regulation, especially in all cases where one has to contend with water hammer, reluctance variable loads, etc., but should never be advocated as the only method of procuring regulation. It has been shown that with good design in the plant the demand for power storage will be materially reduced, if not done away with altogether.

When a point is reached in the design of an installation, beyond which it is not thought expedient to reduce these bad effects by further expenditure, the question of power storage can be considered It should be sufficient not only to take care of the variations of the load while waiting for the governor, but also for the flume effects which have not been prevented by the general design.

In presenting the following equations the writer has no intention of claiming any great degree of accuracy for this method, as the full data in any practical case cannot be obtained exactly, and at best our work is only an approximation to the actual conditions prevailing. It was thought, however, that a study of some of these points may be of some value in bringing out a few of the most important influences that effect the power storage.

FLYWHEELS.

The most convenient way of providing this power storage capacity in any revolving shaft is by the use of flywheels.

We have shown in the foregoing the necessity for such a storage of energy in any plant, where the conditions do not meet the requirements of good regulation.

The problem now before us, is to determine the power storage capacity of the plant that will be sufficient to meet the requirements. Before we can attack this problem we must determine as accurately as possible what these requirements are. It has been already pointed out, that the necessity for power storage arises from the fact that the supply of power to the wheel, and demand of power from the operated machinery do not remain at a fixed ratio to one another, and that with any change in the demand of power from the shaft, the equilibrium is destroyed, which requires some time before it can be restored.

One of the most important influences that affect the demand for power storage is this time loss which occurs between the demand and supply. To determine this accurately is impossible, as these losses may arise from different reasons. The time loss which occurs in the supply pipe has already been considered. We have also the time lost from want of sensitiveness in the governor, and from bad gate rigging, as well as the time required for the governor to effect the required movement of the gate. Though we cannot obtain this time accurately, we can obtain values which are fairly close approximations. In any case, if the power storage is sufficient to take care of the speed under violent fluctuations in the load, that would otherwise endanger the safety of the plant, we may be sure that for ordinary normal conditions of operation, the speed will show very little variation. If we then determine what power storage will be required for safety in one of these cases, we may neglect the small changes of load and time losses which occur constantly under normal conditions.

Before this phase of the subject is dealt with it would be as well to consider, somewhat, the theory of the flywheel itself.

The kinetic energy in any revolving mass is represented by the formula:

$$K = \tfrac{1}{2} I \omega^2 \qquad (6)$$

Where K is the kinetic energy in foot pounds per second,
I is the moment of inertia of the revolving mass about its axis.
ω is the angular velocity in radians per second.

Writing this formula in terms of the revolutions per minute, we have:

$$K = \tfrac{1}{2} I \left(\frac{2\pi N}{60}\right)^2$$
$$= \frac{\pi^2}{1800} I N^2$$
$$= .005483\ I N^2 \qquad (7)$$

Now as I is a constant for any flywheel, we may write the formula:

$$K = (.005483\ I)\ N^2$$
$$= M N^2 \qquad (8)$$

Where M is also a constant for the flywheel; and which, when multiplied by the square of the revolutions per minute, gives the total kinetic energy present in the wheel. This is the amount of energy in foot pounds, which, if acting for one second, must be expended on the wheel before it can be revolved at N revolutions per minute; or the amount that will be required to stop it in one second if it is revolving at that speed.

To show more clearly the influence of the value of I on the stored kinetic energy, and the revolutions per minute, a number of curves have been plotted from the following equations, which were obtained by selecting values for I ranging from 2,000 to 20,000, and introducing them in equation (7).

$$
\begin{aligned}
&K = .005483 \times I N^2 \quad \text{or} \quad K = M N^2 \\
&1.\ K = .005483 \times 2{,}000\, N^2 \quad \text{“} \quad K = 10.966\, N^2 \\
&2.\ K = .005483 \times 4{,}000\, N^2 \quad \text{“} \quad K = 21.932\, N^2 \\
&3.\ K = .005483 \times 6{,}000\, N^2 \quad \text{“} \quad K = 32.898\, N^2 \\
&4.\ K = .005483 \times 8{,}000\, N^2 \quad \text{“} \quad K = 43{,}864\, N^2 \\
&5.\ K = .005483 \times 10{,}000\, N^2 \quad \text{“} \quad K = 54{,}830\, N^2 \\
&6.\ K = .005483 \times 12{,}000\, N^2 \quad \text{“} \quad K = 65{,}796\, N^2 \\
&7.\ K = .005483 \times 14{,}000\, N^2 \quad \text{“} \quad K = 76{,}762\, N^2 \\
&8.\ K = .005483 \times 16{,}000\, N^2 \quad \text{“} \quad K = 87{,}728\, N^2 \\
&9.\ K = .005483 \times 18{,}000\, N^2 \quad \text{“} \quad K = 98{,}694\, N^2 \\
&10.\ K = .005483 \times 20{,}000\, N^2 \quad \text{“} \quad K = 109{,}660\, N^2
\end{aligned}
\qquad \ldots\ldots(9).
$$

Figure 2 shows these curves plotted from the above equations.

From an examination of these curves and equations, we can draw the following conclusions:

1st. That for the same value of I or M, and for the same change of N in per cent., we have a greater range in the values of K when the change of N is positive, than when it is negative. That is to say; that for any given flywheel there will be more energy required to increase the speed 1 per cent., than would be necessary if the speed were to be reduced 1 per cent.

2nd. That for a given normal speed, N, and a given change in N, in per cent., there will be the same change per cent. in the kinetic energy, for all values of I. In other words; if we have a shaft revolving at a given normal speed, and change the speed say 2 per cent. in each experiment, we will find that the kinetic energy will

change the same in per cent., for all sizes of flywheels. The total change in energy, however, will be directly proportional to I, or M.

3rd. If we select any two values of N on the curve of any given I, and change both the speeds a given per cent., we will find that the greatest per cent. of change in the kinetic energy will occur for the higher value of N; or with a given flywheel, the greatest change in per cent. of the kinetic energy will occur at the higher speeds, for the same per cent. of change in the revolutions per minute.

From the first we see, that the speed will change more quickly in the case of a decrease in the load, than for an increase of the same amount. In the second case, when the speed and its limit of varia-

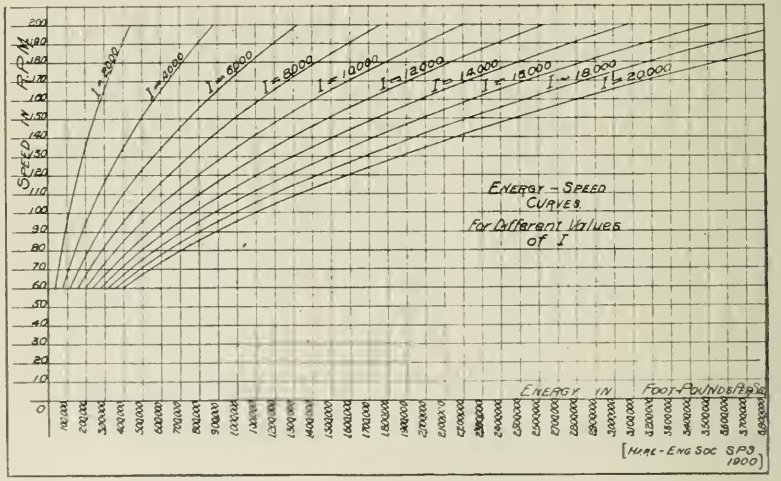


Fig. 2.—Kinetic Energy—Speed Curves, for Flywheels.

tion are given, we have the available energy that we can take from, or add to, the shaft, directly proportional to the moment of inertia. From the third we see, that our flywheel should revolve as fast as possible, in order to obtain the best results.

Before we can design a flywheel that will meet the requirements of service, we must know; first, the maximum load change that is likely to occur; second, the time required for the water in the supply pipe to reach the condition of steady flow, after the gate opening has been changed; and third, the variation of speed that is allowable under this load change.

If our plant is an electric one, the greatest variation of speed will most likely occur when the full load is thrown off instantly. As has already been pointed out, there is no time lost in this case in waiting for the supply pipe to conform to the new gate movement, if we have provided for water hammer effects; but there will always be some time lost in the movement of the governor and gate. If the change of load is an increase, we must wait for the water in the supply pipe to reach the normal conditions for the new gate opening. The variation of speed allowable will depend to some extent on the flywheel itself. In no case can we run a flywheel at a higher rim speed than 75 feet per second, if made of cast iron, but we may by shrinking steel bands on the rim, raise this limit to 160 feet per second. In designing our flywheel we must not let the wheel exceed this safe limit, which is fixed, once we decide on the nature of the material and method of construction.

These quantities are related to one another, and can be written in one equation.

Writing equation (6), we have: $K = \frac{1}{2} I\omega^2$

differentiating, $dK = I\omega d\omega$

let $dK = F\,dt$, and $\omega = \frac{\pi N}{30}$ where F is the force in foot-pounds acting in the time dt, and N is the speed of the shaft in revolutions per minute.

Introducing these values and equating for I we have

$$I = \frac{F\,dt}{\frac{\pi N}{30}\,\frac{\pi}{30}\,dN}$$

$$= \frac{900\ F\ dt}{\pi^2\ N\ dN} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (10)$$

If the load change is expressed in horse power, we can write F in terms of the horse power, as $F = 550\ H$, and we get:

$$I = \frac{900 \times 550\ H\ dt}{(3.1416)^2\ N\ dN}$$

$$I = 50153.7\ \frac{H}{N}\,\frac{dt}{dN} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (11)$$

This equation may be used in this form to determine the moment of inertia required in the whole revolving mass. If we let

H = the number of horse power thrown off or on the wheel,

N = the normal speed of the turbine shaft in revolutions per minute.

dN = the per cent. variation in the speed,

dt = the time during which the energy of the revolving parts must retain the speed variation within the limit dN.

We can write equation (11) in terms of M, as

$$M = .005483\ I \quad \text{..... from (8)}$$

Combining with equation (11) we get;

$$M = .005483 \times 50153.7 \frac{H}{N} \frac{dt}{dN}$$

$$M = 275.05 \frac{H}{N} \frac{dt}{dN} \quad \text{.....(12)}$$

which gives the constant M for the revolving parts.

The value of I as found above gives us the moment of inertia of the whole shaft and revolving parts. If we can determine the value of I, of the turbine runner itself, as well as of all other heavy pulleys, etc., on the shaft, and subtract their sum from the value of I, calculated from equation (11), we will have the value of I, that is still required. This is the moment of inertia of our flywheel which we will call I^1.

The flywheel can be approximately designed from the equation

$$I^1 = \frac{wf\ (d_2^4 - d_1^4)}{\frac{32}{g}} = \frac{wf\ (d_2^4 - d_1^4)}{327.58} \quad \text{.....(13)}$$

by putting in the value of I^1, previously found, or by using equation for M. We may write:

$$M^1 = \frac{wf\ (d_2^4 - d_1^4)}{59744.3} \quad \text{..... (14)}$$

In both these equations,

w is the weight of one cubic foot of the material in the rim.

d_2 is the outside diameter in feet,

d_1 is the inside diameter in feet,

f is the face of the wheel in feet.

This is of course neglecting the arms and hub of the wheel, which is a fairly close approximation for most cases.

TURBINE GATES AND RIGGING.

There is another feature in the design of a water power plant, which must be considered as of no small importance to good regulation, and that is the design of the turbine gates, and the method of connecting them to the governor.

When we are governing turbines of large diameter, we must of necessity have large and ponderous gates; and as these gates must be moved promptly and accurately, to conform to the conditions of the load, it is essential that they be made to move as easily as possible, so as not to introduce too much strain on the gate rigging, and governor connections.

There seems to be great difference in the amount of energy required to move the gates of many of the wheels now on the market. From results of experiments made at Holyoke, Mass., it is found that even with wheels of the same size, and running under the same head, the energy required to move their gates varied considerably. Cases have been found in which the energy required to open the gates of a wheel was 2,000 foot pounds, while in a wheel of different design but of the same diameter, and running under the same head, no less than 50,000 foot pounds were required. These differences cannot be said to arise as much from the type of gate used, as to the fact that the design of that particular type was faulty.

In general, the duty of a turbine gate is to change the amount of water entering the wheel, while at the same time not to interfere with its efficiency. There is not a gate on the market that does not introduce a hydraulic loss, and consequently, a loss or diminution in efficiency, when it is partially closed. This is a problem which has yet to be completely solved, but although we have not reached perfection, there are wheels with gates of different types in operation, which are giving fairly good satisfaction, and efficiency, under all conditions of service.

The question of loss of efficiency when the gates are partly closed, is of considerable importance to the designing engineer. If the governor, when acting, moves to a position which would represent

the correct gate opening, were the efficiency constant throughout the travel of the gate, the power exerted by the wheel would not correspond to the gate opening, and therefore an error would be introduced in the regulation. The movement of the governor can, however, be made to compensate for this.

It is necessary then, before we can determine the proper gate opening for a given amount of power required from the wheel, to know the curve of efficiency of the wheel for various degrees of gate. Many wheels are built with their highest efficiency at part gate, usually seven-eighths, thus allowing a margin for variation with an almost constant efficiency. In cases like this, when regulating under small variations of load, the influence is not felt to the same extent; but when we have to consider the gate opening for large variations of load, the efficiency of the wheel at partial gate must also be taken into account.

The term gate opening, as used here and in general practice, does not mean the opening of the gates in square feet, but the proportional supply of water to the wheel, taking the maximum discharge, when running at normal speed, as unity. In this sense it will apply equally well to all types of gate, while if it meant area, the discharge would be different for each make of wheel or design of gate in use, and we would have no basis of comparison between different wheels.

BALANCING GATES.

One of the most important features to be considered when designing a rigging for a turbine gate, is perfect balance. With many types of wheels of faulty design on the market, this may become a difficult matter, but if the wheel itself is of good make, there should be no difficulty in securing fairly good results.

When one considers the weight and size of some of these large gates, and also the surprisingly short space of time in which they will have to be moved, he will see, that in order to minimize the strain on the governor mechanism and connections, it is absolutely necessary that the whole rigging must be in balance. This refers not only to mechanical balance, which would be the case were there no water in the penstock, but to water balance also, that is to say, the water itself must have no tendency to either open or close the gates, at any

point of their travel. If the gate mechanism is in perfect balance, the governor can handle the gate with much greater ease; and, therefore, can be made lighter than otherwise. This is always an advantage, if strength and precision are not sacrificed, as it can act more quickly.

In all cases where gates are out of balance, not resulting from the action of the water itself, the simplest remedy is to balance by means of counter-weights suitably attached. It should not be forgotten in this connection, that as it is sometimes necessary to move the gates, and therefore the counter-weights, suddenly, that it is important in order to reduce as far as possible all sudden strains on the governor connections, to reduce to a minimum the inertia of the counter-weights. As the kinetic energy of the weight is proportional to the square of its velocity it can be seen that a large weight moving slowly, is preferable to a lighter one moving at a higher velocity. This can easily be obtained by any suitable system of connections.

Gates which are out of water balance to any considerable degree, cannot be governed accurately by any method. The fault lies in the design, and can only be corrected by a new design, which takes into account this only too often neglected phase of the subject.

CYLINDER GATES.

Cylinder gates, when used on vertical wheels, are always out of balance on account of their weight; and also to some extent out of water balance. The former defect can be easily offset by means already described, and where the gates are well designed, the latter does not present any considerable difficulty to good regulation. Some water wheel makers are getting entirely over this difficulty by enclosing all the running gear of the gate under the dome. As in this case the entire gate is submerged at all times, there can no difficulty arise on this score.

Some cylinder gates are out of water balance because of having fingers or auxiliary guides cast on them in order to facilitate the flow of water into the wheel, and raise the efficiency when running at partial gate. It is believed by some hydraulic engineers that these fingers, not only do not add to the efficiency to any extent; but that they are the direct cause of a good deal of the difficulty experienced in moving the gates, and therefore are not considered as being of any

value. It can easily be seen that the water in sweeping into the openings of the guides will press down on these projections with considerable force, which cannot but be detrimental to accurate government.

WICKET GATES.

This type of gate, when properly designed has much to commend it. The gates are hung around the casing of the wheel, and serve the double purpose of guides as well as gates. When hung properly they should have no tendency to either open or close by the action of the inflowing water. This is successfully accomplished by the best makers who use this type of gate. For regulation, it leaves nothing to be desired when of good design; as the gate being in water balance, can be moved with the greatest accuracy and quickness, without introducing needless strains on the governing mechanism.

There are certain makes of wheel on the market, which are fitted with this type of gate, that are anything but satisfactory. Lost motion is a frequent fault, and by this is meant that when the governor moves the gate to a certain point, the action of the water causes them to suddenly move first one way and then the other, because the connections to the spider arms are not positive, allowing play or motion lost. The result of this defect will be at once seen. At this critical point the gates move independent of the governor, which causes fluctuations in the speed. The governor, in attempting to correct this variation, only intensifies the disturbance, with a result that the speed of the plant cannot be kept constant, when the gate is at or near that critical point. Good construction insures absolute rigidity of the gate at all times. When under the influence of the governor, the motion must be perfectly restrained, by which the gate is brought to its proper position, and held there.

When wicket gates are hung near one end, and operated by means of the spider arms from the other, they are very often out of water balance. In some cases, the strain on the mechanism is sufficient to cause excessive wear or other damage, besides introducing loads on the governor and connections, which are entirely unnecessary.

GOVERNORS.

A governor, in the case of any prime mover, is a mechanical device, which automatically increases or decreases the power supplied

to the motor, to compensate for a corresponding decrease or increase in speed, resulting from changes in the load. It is evident that the most any governor can do, is to partly close the gates on an increase of speed, and to open them when the speed falls.

A properly constructed governor will open the gates of the water wheels only as fast as gravity, acting on the pipe line, can follow up, thus retaining a constant pressure in the penstock, and will also close the gates only as fast as the water hammer effects can be disposed of, without raising the pressure in the penstock to any extent. But this is not all, for a governor must, after being put into action by a change in speed, stop the movement of the gates at the correct place, and not overshoot the mark.

Let us consider the case of a wheel running normally, controlled by a governor that does not move to the correct position. Let us suppose that there is a slight increase in the load. The first result shown is a decrease in the speed. The governor being thus energized, opens the gates wider; but instead of stopping at the correct position, overshoots the mark. The pressure in the pipe will momentarily drop, which produces a decrease in the power supplied to the wheel. This makes the wheel run still slower, and as a result, the governor opens the gates wider. The gates are now open too wide, and as during this time the column of water in the pipe line has increased in its velocity, we have more power being supplied to the wheel than was required. As the speed, under these circumstances, will increase and rise above normal, the governor will attempt to check this by partly closing the gates. As we have already pointed out, the velocity in the pipe line had increased to its original value, and an attempt to throttle the discharge, is immediately followed by water hammer effects, and a rise in the pressure. This causes an increased flow through the wheel, which though only momentary, represents an actual increase in the power supplied to the wheel, causing the governor to still further shut off the water.

It is now easily seen that if we have a governor sufficiently sensitive to feel slight changes in speed, and prompt to act, but not capable of checking itself when the correct position is reached, we have a very undesirable condition of things, called "hunting" or "racing." The periodic fluctuations of speed will be of increasing amplitude, even if no further load changes occur, which will in itself destroy

regulation. In attempting to obviate this difficulty, some inventors have provided their governors with dash pots or dampening devices, which act very well when properly adjusted; but if they retard the action of the governor too much, are not desirable.

From the foregoing statements we see that it is necessary for a governor; 1st, to act quickly, i.e., to be very sensitive to slight changes in speed; 2nd, to act as promptly as possible in *beginning* its regulation stroke, and 3rd, to gradually come to rest at the exact position which conforms to the new condition of the load. The time required for the governor to settle down, will depend on the previous design of the plant, and on other considerations mentioned elsewhere.

This action is what is known as "dead beat," and is recognized, as being a very essential feature in a water wheel governor.

A governor should also be isochronous, or capable of running at different positions of the gate for the same speed. That is, the governor would stand in equilibrium, at any position, from friction load to full load, and always move the gate so as to bring the speed to normal. Nearly all the governors on the market, and certainly the best ones, embrace this principle to a greater or less extent; in fact it is useless to talk of a governor that is not designed to work along these lines.

One of the most important, and now recognized as one of the necessary requirements of a good governor, is the embodiment of the relay principle. This means that the governor works by instalments, cutting itself out of action automatically, as soon as it has operated.

This feature has been introduced to prevent "hunting," which it effectually does. In many relay governors, the motion of the driving mechanism is communicated to the gate rigging, through pawls, which are thrown in or out of action by the movement of the centrifugal balls. If a change of load occurs, the balls take up a new position, and in doing so, drop one of the pawls. The gate is now put into connection with the shaft of the water wheel, and is moved towards its correct position; but instead of being moved the entire distance corresponding to the load change in one stroke, the gate is only moved part way, and is disconnected. This is effected by arranging the mechanism of the governor, so that the movement that caused the gate to take a new position, also disconnects the governor from the gate. The governor on its return stroke will again engage

the gate through the pawls, and another partial movement is effected. These partial movements follow each other very quickly, but still slow enough to allow the governor to adjust itself to the new conditions, after each movement. In this way, the power storage in the flywheel is more fully taken advantage of, as each motion of the governor is made under slightly different conditions from the preceding one, being nearer to the ultimate normal position of the gate for the new load.

It can easily be seen, that if the governor is properly adjusted, the gate movement will never exceed the correct position, and therefore hunting or racing is prevented.

Perhaps the latest principle to be embodied in water wheel governors, is what is known as the returning principle. Governors designed to act in this way, will always bring the speed of the prime mover back to normal, under all conditions of load.

Let us suppose a governor of this kind in operation, and as change of load occurs, the governor immediately operates on the gates, bringing them to their correct position. Now if left in this way, the change in the position of the centrifugal balls, resulting from the new gate position, would again actuate the governor, which would start hunting for the correct position. In returning governors, this is prevented by their mechanism, which acts in such a way, that the governor is prevented from working while the speed is coming back to normal. These features will be better shown in the descriptions of the two governors presented with this article.

"LOMBARD" GOVERNOR.

In Fig. 3 is shown a governor which is in use in many water power plants on this continent. It is classed as a hydraulic relay-returning governor, as it embraces in its action both of these principles.

It consists of a very sensitive speed indicator, a series of hydraulic governing cylinders, with their valves, by which the wheel gate mechanism is moved, and pressure and vacuum reservoirs, with their pumps for retaining the respective pressures in the tanks.

In Fig. 3 is shown a side view of the governor, while Fig. 4 shows a clearer view of the details of the upper mechanism.

In Fig. 3 will be seen the tanks situated under the bed of the governor. The smaller tank "1" contains a vacuum, while "2" is partly filled with very thin petroleum engine oil, and partly with air. The air in this tank is retained at a pressure of about 200 pounds per square inch by a pressure pump, which is also constructed to exhaust the vacuum tank "1." This pump is not shown in these cuts, but is situated on the other side of the cylinder "62," and driven from the

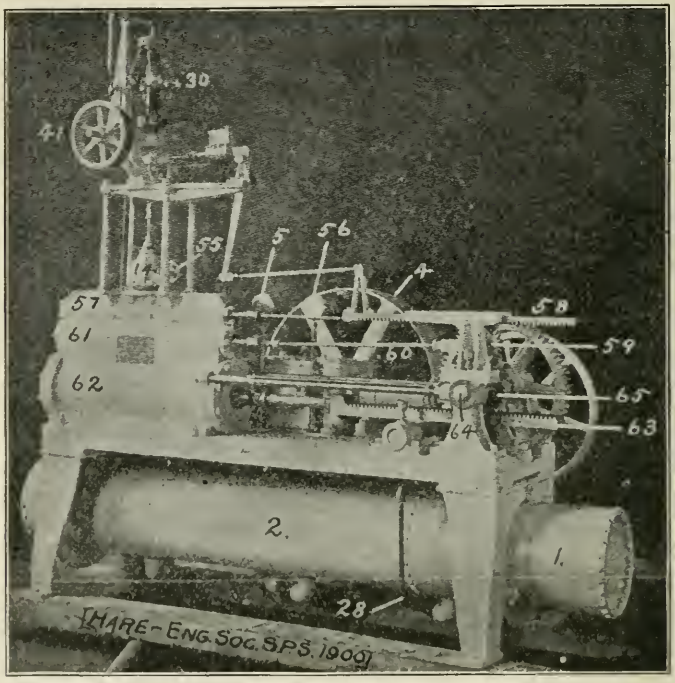


Fig. 3.—"Lombard" Water Wheel Governor (Side view).

shaft of wheel "4." The governor is belted, from the shaft to be governed to the wheel "4," which should revolve between 60 and 90 R. P. M.

In Fig. 3, "5" is a pressure gauge which indicates the pressure carried on tank "2," while "56" is a vacuum gauge which serves the same purpose for tank "1."

A safety valve is situated between the delivery of the pressure pump, and the pressure tank "2." It is adjustable, so that the pres-

sure carried may be varied at will to suit the requirements of the case. A pipe leads from the bottom of the pressure tank "2" through the throttle valve "55" to the fluid filled valve "14," which is operated by the centrifugal balls "30."

The vertical piston valve, "14," lets oil under tank pressure into either end of the small horizontal cylinder, "57." The piston rod of this cylinder is connected to the rack "58," which moves in a sleeve, and runs on top of the floating gear, "59." This gear has no fixed centre, but to its axis is attached the piston rod "60," which actuates a large cylinder-valve in cylinder "61." This valve is situated directly above the main cylinder, "62," and serves to port oil into it under tank pressure. Cylinder "62" transmits its energy through the rack, "63," and shaft, "64," to the water wheel gates.

We will now consider the course of events which take place, when a portion of the load on the water wheel goes off instantly. The speed will immediately begin to increase, which causes the balls, "30," to fly out. This will result in the valve stem, "53," being depressed, carrying down also the fluid filled valve, "14," and letting oil into the right hand end of cylinder "57." As the piston of cylinder "57" travels inward, it carries with it the rack, "58," which also moves the floating gear, "59," and its rod, "60," in the same direction. This movement of rod "60" and the piston valve attached thereto in cylinder "61," will let oil into the right hand end of the largest horizontal cylinder, "62," causing rack, "63," to travel inward. It can easily be seen that pinion "65" will roll floating gear "59" outward, bringing the piston valve in middle cylinder "61" to its central position, when all motion will cease as soon as the ports are closed, as the piston is locked hydraulically in its position. The water wheel gates are now at their correct position for the new value of the load.

These various motions actually occur so rapidly in succession, that the governor seems to be making one positive motion to the correct position. If the change in the load were of the opposite nature all these various motives would be reversed.

It is evident that if this were all, the governor would not regulate very accurately, as will be shown as follows:—Whenever the piston valve, "14," is moved out of its central position by variations of speed of the centrifugal balls, it would remain so until the balls

came back to their normal position. Also whenever the valve, "14," is not in its central position, the main piston and rack will be travelling in one direction or the other. If the load is suddenly thrown off the turbines, the centrifugal balls will fly out beyond their normal position, and valve "14," will cause the governor to begin to close the water wheel gates. The centrifugal balls do not get back to normal until after the water wheel gates have passed their correct position, and consequently, as valve "14" is open, the governor will move too far. The result of this action would be that the governor which moves very quickly would close the gate too far for the new value of the load, allowing the speed to fall below normal. The whole process would now be reversed and the speed would rise above normal, and the governor would begin to hunt. Because of this tendency, the makers have introduced an attachment which is intended to prevent all racing. It is known as the valve stem equalizer.

In Fig. 4 is shown the top of the governor, showing the valve stem equalizer, "43." This device is simply a dash pot which is capable of fine adjustment by means of the thumb screws "40," "40." The outer shell of the dash pot, "43," is connected to rod "42," while the piston joins on to the rack and pinion. The piston of the equalizer, "43," is provided with valves opening through it in either direction. These valves are held closed by stiff springs, so that the oil, with which the dash pot is filled, will only pass through when large load changes occur, and the governor makes correspondingly large movements from its normal position. By-passes are arranged from one side of the piston to the other, and controlled by the thumbscrews "40," "40." Thus by adjusting these screws we can cause the piston to move easily, or with difficulty, as desired. The dash pot is connected to a rack, whose motion is restricted by the spring "48." This rack engages a pinion on the valve stem, and is so connected as to act, in cases of sudden fluctuations of load, against the centrifugal action of the balls.

This combination of motions is effected in an ingenious manner. The pinion on rod "53," is engaged by the rack, which is connected to the dash pot "43." This pinion is rigidly keyed to rod "53," and is of considerable length, so as to remain in mesh with the rack, while the rod "53" moves up and down. The rod "53" is connected to the sleeve, on which the centrifugal balls are mounted,

by means of a screw thread, and it is so arranged that if the pinion on rod "53" is revolved, it will operate the valve "14," provided the balls do not change their position.

If we now consider again the above case, and suppose that the valve stem equalizer is properly adjusted, we will see that it can prevent racing. If the change in the load is large, the motion of the rod

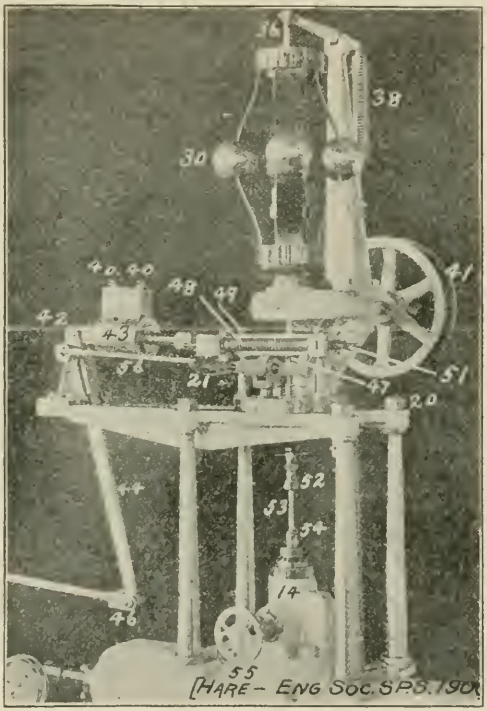


FIG. 4.—"LOMBARD" WATER WHEEL GOVERNOR (Top Mechanism).

"58" will be rapid, and as this is connected to the valve stem equalizer by the lever "44," it will receive a thrust, which, on account of the screws "40," "40," being set, will be partly transmitted to the piston rod, spring "48," and the rack and pinion. This spring is now depressed, and the rack, by its motion, revolves the pinion, and raises the rod "53," stopping the action of the rod "58," and allows

the movement of rod "63" to bring the cylinder valve, "61," to its central position, whence all action ceases; and the wheel gates are at their correct position. It will be seen that the thrust of rod "42" on the one side, and the spring, "48," on the other, will tend to move the piston in "43." If now we prevent the flow of oil by throttling, we can lengthen the time required for the spring, "48," to act, and consequently the point at which the valve, "14," will be closed.

The rotation of the pinion and valve stem serves to close the valve "14," by means of the screw before mentioned, without any additional motion on the part of the balls. Immediately after the closing of the valve "14," the balls will return to the position they held prior to the change in the gate. This would produce a new movement in valve stem "58" and valve "14," and so cause a new movement in the whole governor, were these points not provided for. When the rod "42" and equalizer "43" were moved at first, the spring "48" was depressed. Now this spring cannot return to its normal position without moving the piston in "43," and also revolving rod "58" by means of the rack and pinion. If the screws "40" "40" have been adusted properly the action of the spring "48" in returning to its normal position, retarded by "43," will gradually revolve the pinion on rod "58," at the same time that the governor balls are moving back to their normal position. As both of these actions take place together, and are opposite to each other, the rod "58" is not moved sufficiently to cause any flow of oil in cylinder "57," and the whole mechanism comes back to its original position.

If, on the other hand, the change of speed be slight, the rod "58" will move more slowly, and, as a result, the centrifugal balls will have sufficient time to return to their normal position and close valve "14" before the gates have been moved too far.

"REPLOGLE" GOVERNOR.

In Fig. 5 is shown a relay returning governor, which is widely used and seems to give good results.

When set up for use, the mechanism is driven from the water wheel shaft by a belt on pulley "3," while the centrifugal balls "11" are operated from the same shaft by means of pulley "12," and belt. The water wheel gates are connected to shaft "1" by means of suitable connections. This shaft "1" is revolved by means of the power

transmitted through pulley "3," as shown. When it is required to start or shut down the plant, the gates can be operated by hand by the hand wheel "15" and connecting gears. Shaft "5" is revolved from pulley "12," and carries on it the centrifugal balls "11" and the inertia weight "14." This inertia weight is not keyed to the shaft, but runs on a sleeve, which permits it to revolve through a part of a revolution, quite easily. It is connected to the centrifugal balls by means of two short chains "13," by which too much independent motion is prevented.

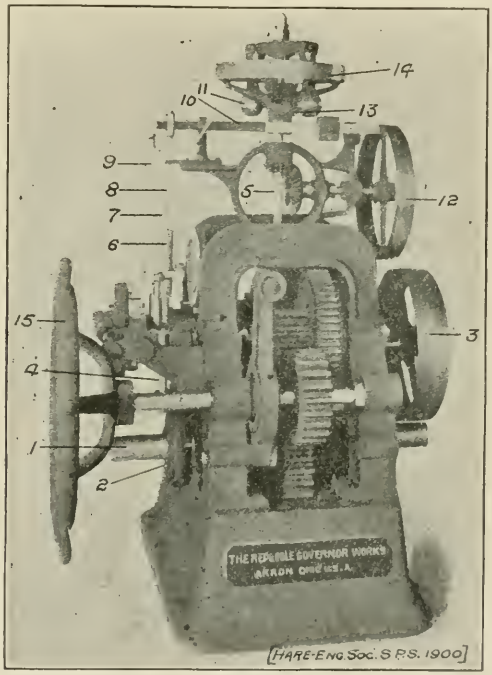


FIG. 5.—"REPLOGLE" WATER WHEEL GOVERNOR.

The inertia weight is connected by means of an annular slot, to the lever "10," so that the vertical motion of the weight is communicated to the lever "10," and which, by means of the rod "9," transmits the motion to the pawls. These pawls—not shown in figure 5—by their motion, connect the shaft bearing the pulley "3," with shaft "1," and so cause a movement of the gates.

The operation of this governor is somewhat as follows:—Let us suppose that everything is running normally. The inertia weight is now revolving at the same speed as the centrifugal balls; but being freely suspended from them by means of the chains "13," it lags a little behind, and consequently the chains are not vertical, and the weight is slightly higher on the shaft "5" than it would be if the governor were not running. If now an increase in the load occurs, the speed of the wheel, and consequently the speed of "12" will decrease. As soon as shaft "5" begins to run slower, the inertia weight, because of the energy stored in it, will move forward, and in doing so it will take a lower position on the shaft "5."

As the lever "10" is connected to the weight it also will fall slightly, and cause the pawls to engage by means of rod "9." Pulley "3" is now connected to shaft "1," and the gates are moved to increase the power. When the proper movement has been effected, the rod "4," which engages cam "2" on shaft "1," is raised and in doing so raises oil cylinder "6" and rod "8," which in turn lifts lever "10" and rod "9" releasing the pawls, and preventing the governor from moving too far. This embodiment of the relay principle is one of the best features of this governor. By adjusting the screw "7" the relative movement of the rods "4" and "8" can be timed to a nicety, the adjusting depending on the general conditions under which the governor is operating

Should the load decrease, the reverse operation will take place. The inertia weight will now lag further behind, because of the increased speed, and will therefore rise on shaft "5," carrying with it lever "10" and rod "9," which connects the pawls as before. The cam will act to lower the lever "10" when the correct movement has been completed. Were it not for this attachment, the governor would continue to move the gates until the speed changed. In this case the movement would have been greater than required, and as the speed changed again the governor would again move too far. The result would be severe "racing," or "hunting," on the part of the governor.

The centrifugal balls do not directly act on the lever "10," but only through the inertia weight "14." The governor is much more sensitive this way, than when acting under the balls directly.

The returning principle is also found in this governor by means of which the speed is always brought back to normal. When the governor is set up, it is adjusted so that when the centrifugal balls are revolving at their proper speed, the inertia weight is holding lever "10" in its normal position; or the pawls are both out of contact with the gate-moving mechanism. Now, if the speed does not come back to normal, the centrifugal balls will not come back to their normal position, and consequently, the inertia weight will continue to act on lever "10," causing thereby a movement of the gates, until the speed does return to normal. It should be noted that with the dash pot or oil cylinder "6" between the rods "4" and "8" the motion of "4" is transmitted almost positively for sudden fluctuations of speed, but for slight variations the oil passes through the holes in the piston, and allows the governor to slowly move the gates, without being cut out of action. In very slight changes of load, the governor will bring the speed back to normal, without being cut out of action by the cam; but when the changes are violent, the governor will move to a certain position, when it will be cut out. If this movement was not sufficient to bring the speed back to normal, the governor will be cut in again and will make another movement and be again cut out. This will continue until the descrepancy in the speed is small, when the governor will gradually brings the speed back to normal.

Tests made on a modern number of plants, running under widely varying conditions of service, have shown that the speed of turbines can be controlled, within a small percentage, when the plant has been carefully designed.

In conclusion, the writer wishes to express his gratitude to the Lombard Water Wheel Governor Company of Boston, Mass., and to the Replogle Governor Works of Akron, Ohio, for assistance cheerfully rendered to him when engaged in preparing this paper.

COLD STORAGE.

E. Richards, Grad. S. P. S.

For many years, at least, Canada is destined to be an agricultural country rather than a manufacturing or trading one, and it would seem that one of the most important problems before her is the making of markets for dairy and fruit products. This would enable the tiller of the soil to pursue a more far-sighted and prudent policy than the exclusive production of cereals has proven to be. The present and future fertility of farm lands depend so largely upon the nature of the problem taken either directly or indirectly from them, that it seems a wise policy to encourage in every way the production of stock and dairy produce rather than the growing of grain, hay, etc., with their constant drain upon the fertility of the soil. Great Britain offers a splendid market for such goods but the great difficulty has been found in the lack of proper facilities for the storage and transportation of perishable products. Of late, however, the perfected systems of cold storage and transportation have made it possible that Canadian eggs, butter and fruit, may be placed upon the British market almost, if not quite as fresh, as any offered upon our own local markets.

The first link in this chain of storage and transportation is the cold storage warehouse, to which are brought the goods for chilling or freezing, and storing necessary to make up large cargoes.

It is the intention in this article to discuss briefly, a few of the problems arising in the designing of a cold storage plant.

Cases may be found, where, because of low cost of harvesting and storing ice, it may be advisable to use it as a cooling agent, but in nearly every case the many advantages possessed by a system of mechanical refrigeration will lead to its adoption. It would be found quite impossible to provide for thoroughly efficient cold storage on a

large scale with ice as the refrigerant. As a system, it is not nearly as pliable nor as completely under control as mechanical systems are.

The considerations influencing one in the choice of a site, excepting those of a purely mercantile nature, will be much the same as those in case of any power plant, excepting the fact that a very large amount of condensing water, as cool as possible is needed. A good well of cold water is a veritable gold mine to the operator of a refrigerating plant, as the power required depends so largely on the temperature in the condenser. If it seems that more weighty considerations demand the choice of a site where water is not plentiful, it will be necessary to resort to the use of cooling towers or other means of cooling the condensing water so that it may be used over and over again, only replacing, from time to time, the portion evaporated.

Of the various mechanical systems the ammonia compression is the general favorite; but it will be well to make a canvass of its relative merits before accepting it as the best.

The greatest disadvantage possessed by ammonia as the working fluid in refrigeration, was for many years, and is yet to some slight extent, the difficulty experienced in providing a system of piping and apparatus proof against its strong penetrative properties. This objection has been almost entirely overcome by improvements in fittings and packing.

Ammonia and sulphur dioxide have, theoretically, the same loss of efficiency due to expanding the fluid through an expansion valve or cock, rather than in an expansion cylinder, in which the positive work of expansion might be recovered. Using the constants given by Ledoux for these two agents, this loss is found to be about seven per cent.

Sulphur dioxide, having a much higher specific volume, requires a much more cumbrous compressor, in which the friction losses are necessarily greater, but the working pressures proportionately lower. The latter fact is of no great importance, because the pressures required to compress ammonia are well within the range of pressures used in ordinary steam engineering.

The only other agent used to any extent is carbon dioxide. It requires pressures ranging as high as 1,100 pounds per square inch to compress it sufficiently for condensation at ordinary temperatures

of condenser water. This requires the use of very heavily built fittings and apparatus. Aside from this, the theoretical loss due to expanding the gas through an expansion cock is about thirty-three per cent.

It would, therefore, seem that there is good reason for ammonia being used so extensively. It remains to be shown that there are equally satisfactory reasons why the ammonia should be used in the compression, rather than in the absorption system.

All systems, working between the same limits of temperature, in a reversible cycle, or in a cycle in which all interchanges of energy are reversible, theoretically produce the same refrigerative effect, whether the interchanges are caused directly by chemical action as in the absorption, or indirectly through mechanical energy as in the compression system. At first thought, then, it would seem to be advisable to use the direct rather than the indirect application of the heat energy of the fuel to the working fluid, because in the best heat motor 10 units of heat liberated from the fuel barely produce 1 unit or 778 foot pounds of work. There are, however, two causes which so much modify theoretical results that the compression system actually proves more efficient.

The first of these causes is the evolution of heat from the absorption of the expanded gas in the weak liquor from the generator raising the temperature of the absorber to such an extent, that absorption almost ceases unless the absorber is cooled. This cooling causes a very serious falling off of efficiency from the theoretical. Secondly, the generator causes more or less steam to pass over with the gas to the condenser. This entrained water impairs the efficiency in that it carries off heat from the generator and having arrived at the refrigerating coils prevents part of the gas evaporating by holding it in solution.

Prof. Peabody, in his Thermodynamics of the Steam Engine, gives tests made on compression and absorption plants by Prof. Denton and compares results on the basis of pounds of ice per pound of coal. The compression plant proved to be nineteen per cent. more efficient. The comparison was, if anything, unfair to the compression plant. It was assumed that the absorption plant boiler would evaporate 10 pounds of water per pound of coal, and that the compression power plant would require 3 pounds of coal per horse-power

hour. Now, a good condensing engine requires only about 20 pounds of steam per horse-power hour, which is equivalent to only 2 pounds of coal.

There are some questions, quite important in themselves, the solution of which depends on the capacity of the plant and the amount of capital to be invested.

The most important one is whether to provide a reserve compressor or not. With a single machine, an accident causing a protracted shut-down means a very serious loss. Such a contingency might be partially provided for by dividing the total capacity needed between two or three machines. In case of accident to one, the other one or two might be run at maximum capacity and heavy loss averted. The use of a double compressor would amount to the same thing. If one were disabled, it might be disconnected as quickly as possible and the other worked to its full capacity. Three machines with one always in reserve would be the ideal arrangement.

Another question is that of choosing between direct expansion and brine circulation. In this, first cost plays a very large part. The brine circulation costs more by that of the cooler tank and brine piping. Besides this, it is less efficient. This is due to the lower back pressure in brine systems. But for general cold storage work, requiring a wide variation of temperatures, it proves to be much more flexible and capable of good regulation. The difficulties experienced in securing proper regulation in general cold storage with direct expansion are due to the necessity of maintaining rooms at temperatures differing as much as 25° Fahr. by means of coils containing the expanding ammonia all at one temperature, or nearly so. This may be partially overcome with a double compressor, by connecting the suction of one of the returns from one section of the cooling rooms at the lowest temperatures, and the other to the returns from the remaining rooms at higher temperatures. With a double acting machine the suction of one end could be connected to one part of the rooms, and the suction of the other end to the other part. Suppose a plant, in which the power would be about equally divided between some freezing rooms to be maintained at temperatures ranging from 10° to 20° Fahr., and butter, egg and fruit rooms ranging from 25° to 35° Fahr. In case this were divided into

two systems the greatest difference of temperature in one system would be 10°.

No investment in connection with cold storage pays better than that placed in good insulation. Wide differences of opinion are found regarding the construction of walls of refrigerated rooms. Some advocate open air spaces, while others advise filling them with mineral wool, cork dust, and even planing mill shavings.

The construction of insulation should conform to some general principles, which may be briefly stated as follows:—

(1) The flow of heat through any medium is nearly proportional to the difference in temperature between the spaces on each side of it. An insulation which would be quite sufficient for a room to be mantained at 35° or 40° might prove utterly inadequate for a room to be maintained at 10°.

(2) The best insulation cannot prove too good, and will certainly be the cheapest in the end.

(3) All materials should be as nearly non-absorbent as possible, and should be free from odors. In wood, spruce is the most suitable, as it is odorless and free from knots.

(4) Every precaution should be observed to prevent the penetration of air and moisture.

(5) Air is one of the best non-conductors of heat, if still, but a poor one if allowed to form convection currents, which it will do between surfaces, differing only very slightly in temperature, if unrestrained.

(6) The use of all porous substances, which settle and lose their porous qualities should be avoided. A permanently porous substance, non-conductive of itself, is of value as it thoroughly prevents all circulation in an air space.

Fig. 1 represents an insulation for the outside walls of rooms for temperatures as low as 10°. A metallic weather cover is shown on the outside. A double layer of good quality insulating paper is placed between the double layers of spruce lumber. The air space between the studding, which is two feet apart, is divided up by seven-eighths inch shelving, driven in tight between the studding at intervals of two feet. The lumber should be dressed on one side,

at least, to ensure a uniform thickness. The inside layer of boards should be tongued and grooved.

Fig. 2 shows a construction inside a brick wall for the same temperature. Two coats of pitch or asphaltum are applied to the wall before proceeding to build the insulation. The construction of partitions, ceilings, and floors is also shown. The partition with two air spaces is for rooms differing as much as twenty-five or thirty degrees. The one with only one air space is for rooms not differing more than ten or fifteen degrees. The second layer of paper is laid so as to cover the joints in the first.

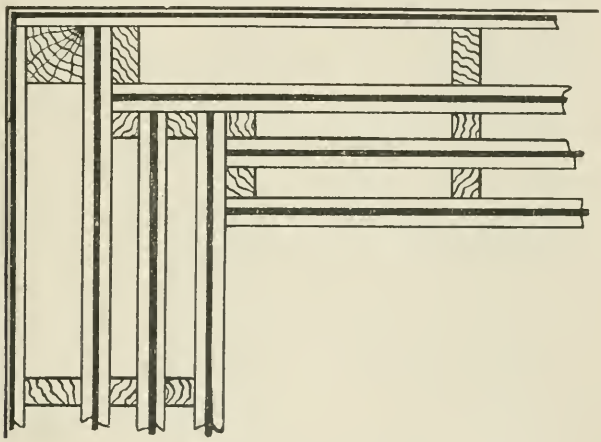


Fig. 1.

To provide for scrubbing out rooms without danger of water leaking through, destroying the insulation, the flooring should be heavy and caulked like the decks of ships. This would be preferable to the best matched flooring without caulking. This would be quite necessary in rooms for freezing fish, and in rooms where there would be any likelihood of drip from pipe coils.

The proper storage of eggs presents greater difficulties than that of any other line of produce. The temperature, humidity, and circulation of the air in the room are all important factors in their preservation. The opinion of the large majority of those having a wide experience in egg storage is in favor of a temperature between 30°

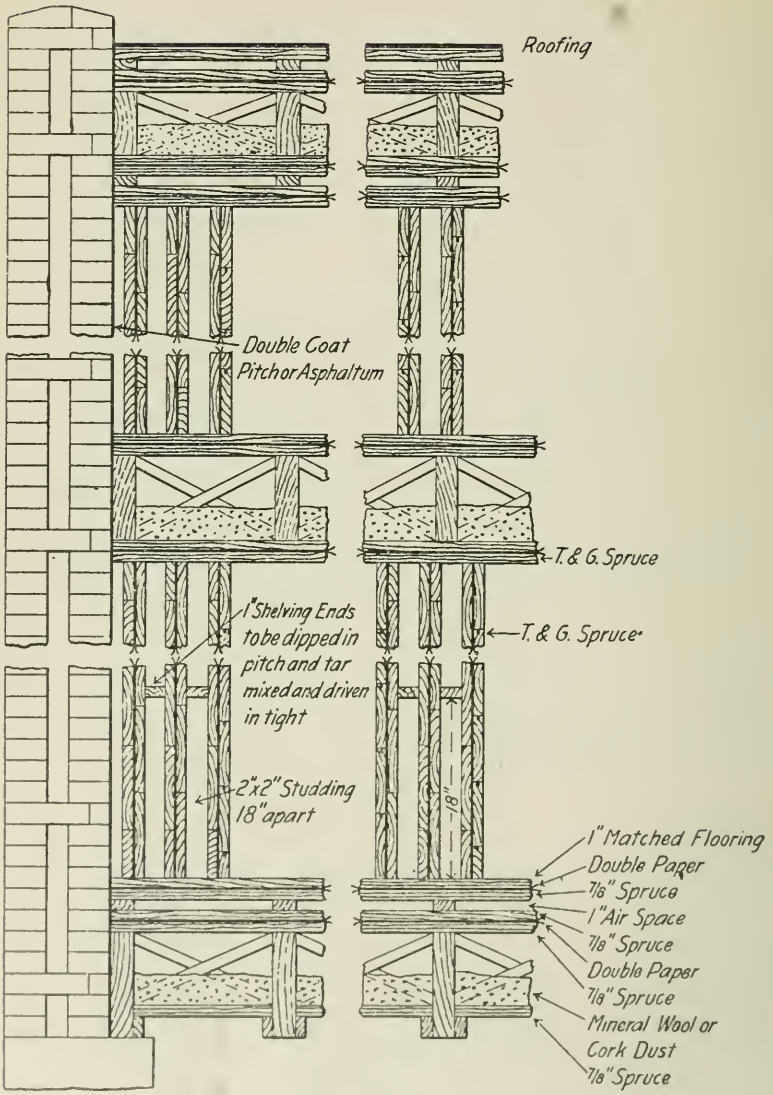

Roofing
Double Coat
Pitch or Asphaltum
T. & G. Spruce
1" Shelving Ends
to be dipped in
pitch and tar
mixed and driven
in tight
T. & G. Spruce
2"x2" Studding
18" apart
18"
1" Matched Flooring
Double Paper
7/8" Spruce
1" Air Space
7/8" Spruce
Double Paper
7/8" Spruce
Mineral Wool or
Cork Dust
7/8" Spruce

FIG. 2.

and 32°. A fresh egg freezes at about 28°, and the best results have been attained in temperatures as near to this as possible without danger of freezing them. A margin of 2° would be the least possible, even with the greatest watchfulness. The proper humidity and circulation is a more difficult matter to determine. They must be considered together, because, a humidity which would cause mildew in a sluggish circulation might even cause undue evaporation in case the circulation were brisk.

When ordinary gravity circulation is used the following table gives the humidities which do not seem to cause mildew on the one hand nor excessive evaporation on the other.

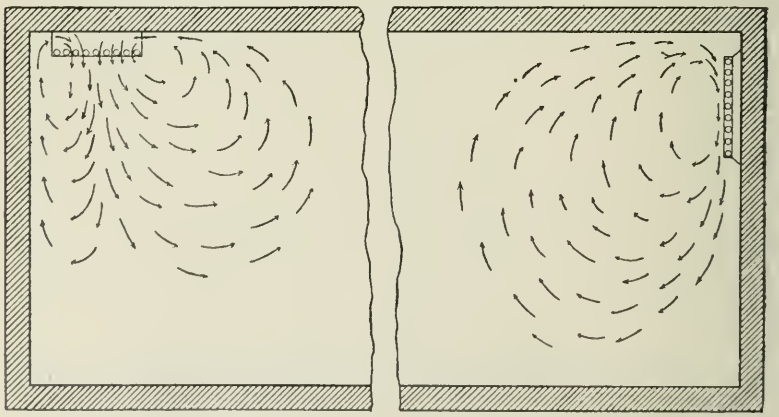
Temperature in Degrees Fahr.	Relative Humidity.
28	80
29	78
30	76
31	74
32	71
33	69
34	67
35	64
36	62

Relative humidity is the ratio of moisture in any atmosphere to that in saturated air at the given temperature. Saturation at any temperature is that condition of the air in which condensation just takes place, or the condition of the air which has its dew point at the given temperature. This relative humidity can best be determined by means of a sling psychrometer. This instrument is simply two thermometers mounted on a wooden frame. The bulb of one is enclosed in a little muslin bag. This bulb is dipped in water, preferably at the temperature of the room, and is whirled through the air a dozen times or so. It is again dipped and whirled, and a reading of the difference between the temperatures indicated by the two thermometers is then taken. The whirling and reading is repeated until the wetted thermometer shows a minimum reading. The difference between the readings of the two thermometers may

be translated into relative humidity by means of the following table, issued by the Weather Bureau at Washington:

t (Dry ther.)	Difference between dry and wet thermometers (t-t).												t (Dry ther.)
	0°.5	1°.0	1°.5	2°.0	2°.5	3°.0	3°.5	4°.0	4°.5	5°.0	5°.5	6°.0	
28	94	88	82	77	71	65	60	54	49	43	38	33	
29	94	89	83	77	72	66	61	56	50	45	40	35	
30	94	89	84	78	73	67	62	57	52	47	41	36	
31	95	89	84	79	74	68	63	58	53	48	43	38	
32	95	90	84	79	74	69	64	59	54	50	45	40	
33	95	90	85	80	75	70	65	60	56	51	47	42	
34	95	91	86	81	75	72	67	62	57	53	48	44	
35	95	91	86	82	76	73	69	65	59	54	50	45	
36	96	91	86	82	77	73	70	66	61	56	51	47	

The terms circulation and ventilation are confused by many. Circulation is applied only to those currents in the air of a room due to natural or artificial causes. Ventilation implies a substitution of the air in the room by air from some outside source.



FIGS. 3 AND 4.

Figs. 3 and 4 represent fairly the circulation resulting from two methods of suspending the expansion or brine coils within the room. Figs. 5 and 6 show arrangements which give better distributed and more thorough circulation. Either of the latter will give about the best results that can be obtained with gravity circulation.

Natural circulation must, of necessity, be irregular, depending as it does, so much upon the amount of refrigeration required, and, therefore, it seems necessary to resort to other means to obtain a circulation both positive and well under control.

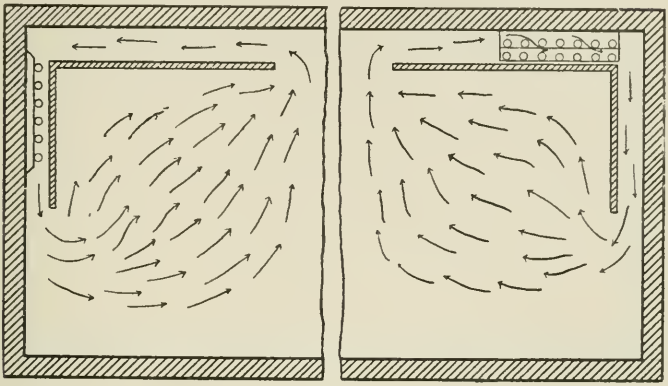


Fig. 5.

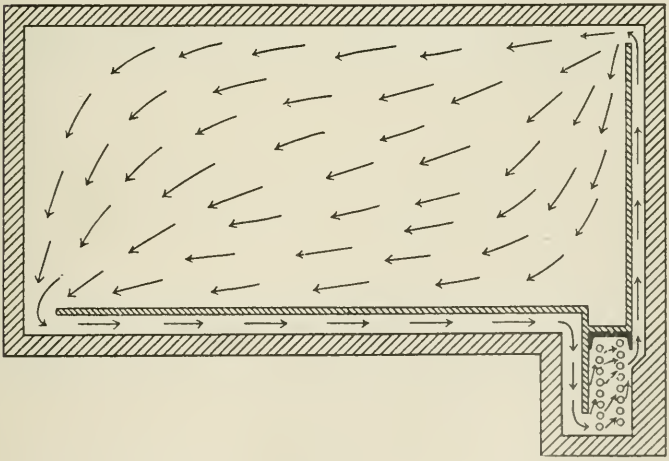


Fig. 6.

Well distributed and thorough circulation is necessary to the maintenance of a uniform temperature throughout the room. Differences as great as 5° have been found in rooms provided with poor circulation. Thorough circulation, also, serves a good purpose in

removing from the immediate vicinity of eggs or fruit the air containing the putrid elements due to the evaporation of the decomposing tissues. This purifies the air in two ways. First, the mere circulation of the air seems to have a purifying effect independent of the absorbent qualities of any surfaces over which the air may pass. Secondly, the moisture in the air congeals upon the cooling coils, and retains much of these impurities with it. It is apparent, however, that an excessive deposit of such impurities on the pipes would prove a contaminating rather than a purifying influence. This will suggest the advisability of placing the cooling coils in a separate chamber with a means of shutting off all communication with the storage room, so that the cooling coils could be melted off and cleansed without affecting the main room.

The fan will offer the only feasible means of providing for such a circulation as is needed for the efficient and thorough preservation of eggs. In a case like this where a high velocity is not required, a large, light, slow running fan offers many advantages over a higher speeded and necessarily heavier one. It will prove more economical of power, as experiments prove that doubling a fan's speed to double its capacity requires much more than twice as much power. With low speeds the centrifugal type will prove much more efficient, besides being more handily arranged in a duct or air passage.

Fig. 7 shows the arrangement of ducts in the British Linde system of forced air circulation, where the cold air enters the room from the side ducts, and the warm air returns by the center one.

Madison Cooper of Minneapolis, in his book, "Eggs in Cold Storage," suggests an arrangement like that shown in Fig. 8. The cold air is forced into the room through small perforations in the sides of the cold air ducts, placed one on each side of the room on the wall near the floor. The perforations are made twice as numerous on the bottom of the duct as on top. There are a few placed in the sides. The fan is placed between this duct, and the cooling chamber. The air passes out of the room again through perforations in the false ceiling, to the cooling chamber. The holes in the ceiling are made closer together in the centre of the room farthest from the ducts.

When the question of ventilation is broached to many egg men, they say their rooms are ventilated sufficiently through the doors, when opened. This may prove sufficient at certain seasons, but it certainly is indefinite and unreliable. Others say it would be well to ventilate if pure air were obtainable, but that they would much

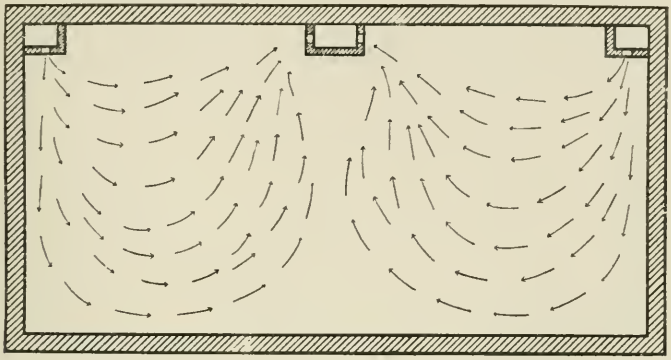


Fig. 7.

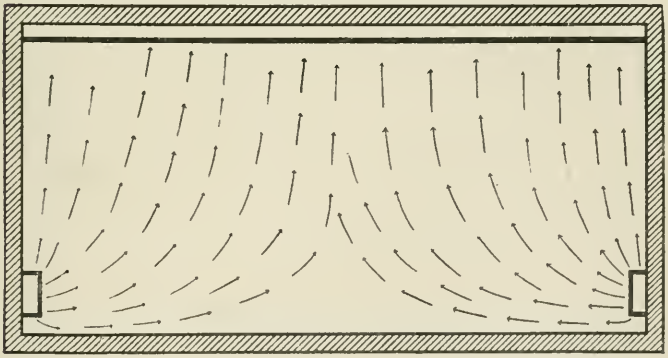


Fig. 8.

prefer no ventilation at all to the introduction of the dust and microbe laden air in our cities. It is quite possible that some of the methods of washing and purifying the air in process of circulation may prove ample, and no ventilation may be needed where they are used. In the British Linde system the circulating air is drawn through brine

dripping over the ammonia coils. This, doubtless, proves quite effectual while the brine is fresh; but it must soon become so contaminated with impurities that its cleansing power would entirely vanish unless means were provided for renewing it from time to time.

Mr. Cooper suggests apparatus like that shown in Fig. 9, for washing, cooling, and drying outside air for ventilating purposes. The air first passes through the washer which is simply a tank with a perforated diaphragm near the top, through which falls a spray of water. The air then passes to the cooler with its brine or ammonia coils, and from there to the drying and purifying tank, con-

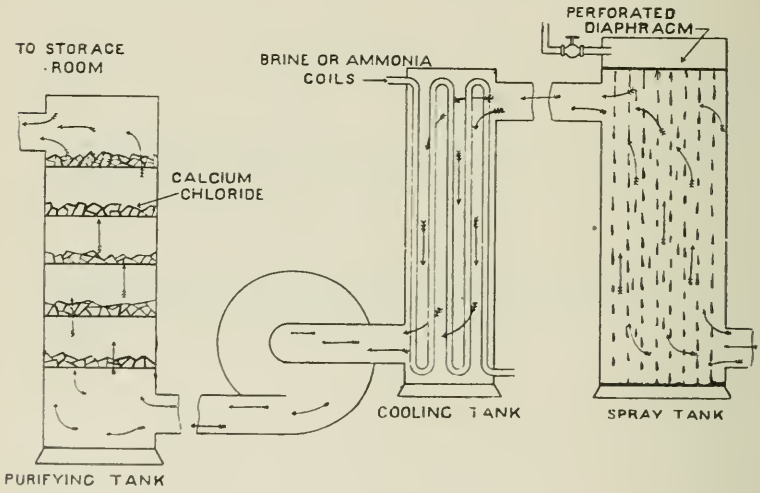


Fig. 9.

aining trays of calcium chloride. The air then passes into the room near the top. Openings of the same size are provided near the floor, through which the foul air may pass. He suggests putting the fan between the cooler and the dryer. In hot weather the ventilation should be done in the early morning, when the air is as cool as possible. At seasons when the outside air is about the temperature of the room, with proper care in choosing a time when its humidity is the same as that required in the room, ventilation could be secured by simply introducing sufficient air with a fan. When the outside air is at a lower temperature it would require

warming. In this case much ventilation might reduce the humidity of the room seriously, and it would be necessary to introduce a certain amount of moisture into the air.

The question is often asked whether eggs may be stored with safety in a room which has been used for apples or other fruits. Experience has proved that it may be done if proper precautions are observed. After the fruit is removed the floors should be scrubbed, and the walls and ceiling swept, and given a coat of white-wash. If the cooling coils are in a separate compartment, it should be treated in the same way.

The cold storage of fruit presents some of the same difficulties found in egg storage. Pears, particularly, give off large amounts of gases, and all fruits do the same to a greater or less extent. For this reason forced circulation would prove superior to natural. Still the latter, if that obtained from such an arrangement of room as shown in Fig. 5 or 6, would give good results if provision were made for thorough ventilation every day or so. The proper humidity is difficult to determine. Most storage men judge by the effect of the atmosphere on the fruit. The humidities given for eggs give good results, as they are about as low as could be used without producing an evaporating effect.

Opinion varies somewhat as to the best temperatures for fruit. The majority of cold storage men, however, favor 32° to 33° for apples, and 35° to 36° for pears, peaches, grapes, and dried fruits.

Butter may be stored successfully in a room with any arrangement producing fair circulation. There is not as imperative a need for thorough circulation, as with eggs and fruit. As to temperature there is great difference of opinion. The trade in this city generally demands a temperature as low as 22°, but it is believed by those who have studied the matter to be a mistake. Creamery butter nearly always is made with brine, which will freeze at this temperature. The freezing of the brine is believed to have a bad effect upon the grain of the butter. On the other hand a temperature of 26° to 28° does not freeze the brine, yet effectually prevents all fungus growth.

Fish and game are frozen up hard, and are kept frozen until needed. Forced air circulation is seldom resorted to except with fish. It has a wonderfully freshening and purifying effect on the

air of a fish freezing room. A combination of forced air circulation and freezing coils within the room, gives most excellent results.

All things else being equal, the larger the room the less refrigeration is required to maintain a given temperature. If the rooms are not provided with stagings, the height will be restricted to avoid having too high piles of goods. Twelve to fourteen feet would seem as great a height as would allow of the easy handling of cases or barrels. The width will depend upon the uniformity of temperature, and thoroughness of circulation required. In egg or fruit rooms with gravity circulation such as is obtained by constructions shown in Figs. 5 and 6, the width should not exceed 20 feet. This dimensions could be increased to 30 feet with a system of forced circulation. In case of butter rooms the size is restricted only by the necessity of maintaining a fairly uniform temperature.

HYDRAULIC AND ELECTRIC ELEVATORS.

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The origin of the modern elevator can be traced back to crude forms of hoisting machinery in use during the earliest ages. All these primitive forms up to the beginning of the eighteenth century consisted of a rope or ropes passing over one or more pulleys, and controlled by winding on a drum or some form of winch. Perhaps the first reference to an actual elevator, *i.e.*, a car capable of moving vertically up or down as desired, is given in a letter written by the Emperor Napoleon I, in which he describes "the flying chair" (la chaise volante) seen by him in Vienna. For many years after the great Corsican's time no appreciable advance was made in elevator machinery till about sixty years ago. About this time the well known belt driven hoisting machine was introduced, in which the hoisting rope from the car is wound upon a drum, rotated by gearing from some arrangement of tight and loose pulleys for reversing the motion of the car. For slow speed elevators, such as for instance in handling freight, or in many situations where a more expensive lift is not required, the old type of belt driven machine is still used very extensively. Improvements have continually been made in these machines, in the control of the winding drum from the car, and in various forms of safety devices, automatic stops, belt-shifters and methods of applying the brake.

What may be called the first really distinctive elevator machine is the direct acting lift, or "Plunger Elevator," as illustrated in Fig. 1. The car, or platform, is supported between guides on a long vertical steel tube or "plunger." Surrounding the lower portion of this plunger is a cylinder of slightly greater diameter, and of the same length, as the plunger. The space at the top of the cylinder between it and the plunger, is tightly packed, such that

on allowing water under pressure to enter the cylinder, the plunger and car are raised. Conversely, by allowing water to discharge from the cylinder the car is lowered. The control of the car is effected in this manner by means of a piston valve similar to that shown in Fig. 2. The plunger elevator is chiefly employed for freight purposes through short distances, and is used very extensively for sidewalk

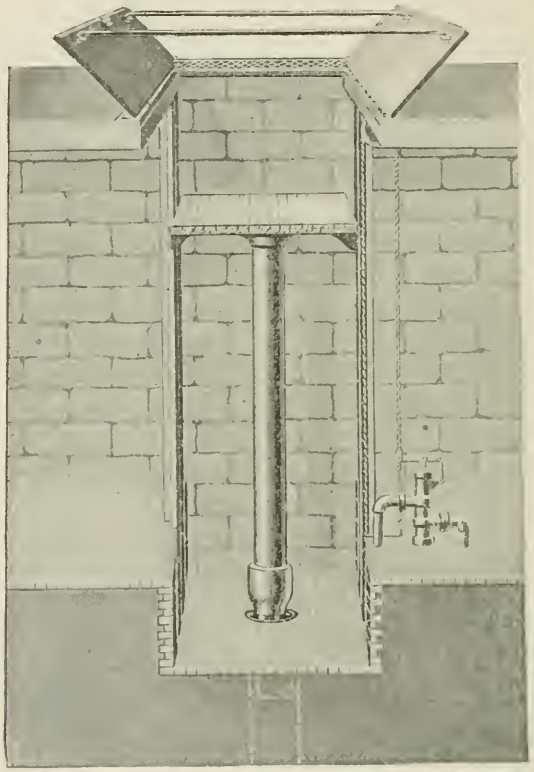


Fig. 1.—Sidewalk Lift Hydraulic Elevator.

lifts. Though generally slow in motion, it is very simple, requires a minimum of floor space, and is capable of handling heavy loads.

The most familiar type of hydraulic elevator for passenger service is shown in Fig. 2. In this case a system of multiplying sheaves is used, by which the motion of a piston in a vertical, or horizontal cylinder, produces a high speed at the car. The main cylinder, as

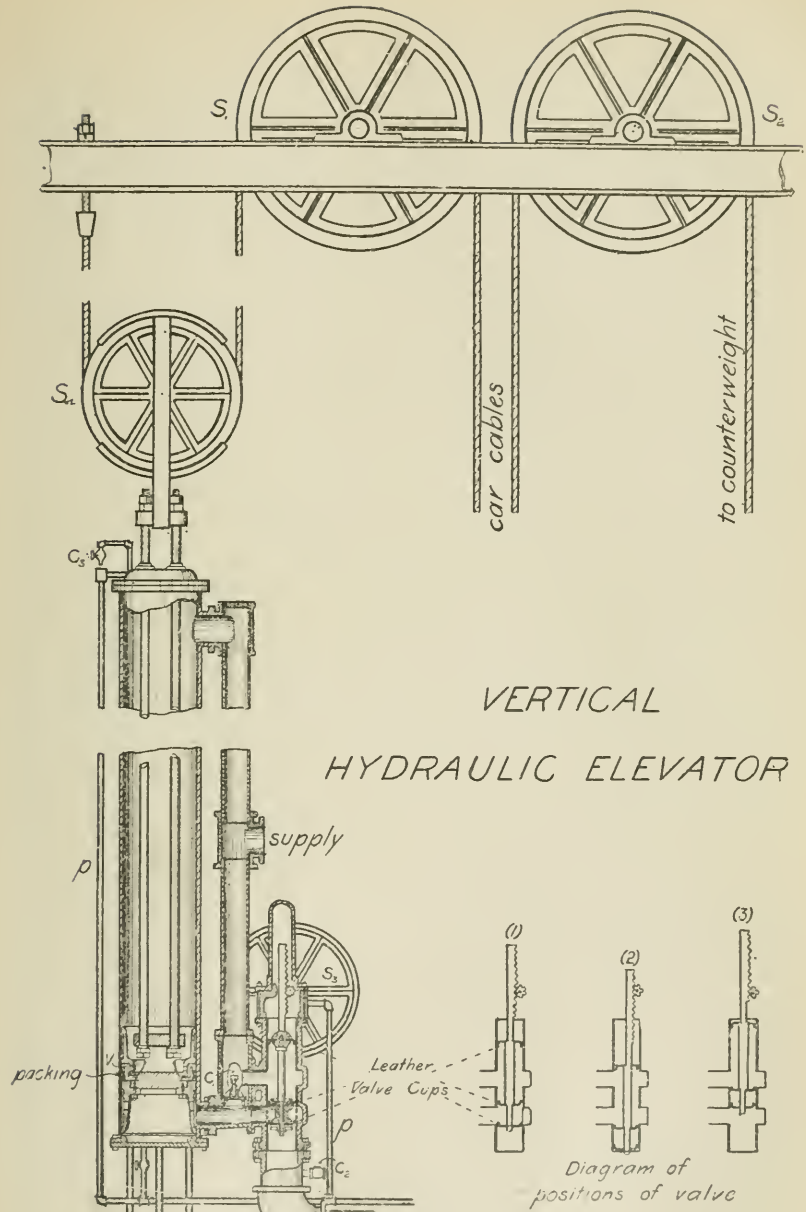

S1
S2
car cables
to counterweight
S4
C3
VERTICAL
HYDRAULIC ELEVATOR
supply
p
S3
packing
V
C
Leather
Valve Cups
p
C2
discharge
(1)
(2)
(3)
Diagram of
positions of valve

FIG. 2.

shown in the figure, consists of a cast iron tube, whose dimensions depend upon the height of the lift, the pressure of water to be used, and the load and speed of the car. The operation of the elevator may be understood from an inspection of the valve at (1), (2), (3), which are diagrams respectively of the position of the main valve when the car is stationary, descending and going up. In (1) the full hydraulic pressure is acting on the upper surface of the piston, yet no motion is possible since the lower portion of the cylinder is filled with water, and no discharge can occur while the valve remains in this position. By raising the valve cups to the position given in (3), this water below the piston is released and the piston is forced downward, thus raising the car. When the car is required to descend, the valve is lowered to the position shown at (2). The pressure of the supply is now applied equally on both the upper and lower surfaces of the piston, and since the water is now free to circulate through the valve ports, the piston moves upward due to the excess in weight of the car and its load over that of the counterweights, travelling sheaves, and piston.

In case the car is stopped very quickly when going up, by suddenly dropping the valve to cut off the discharge, a very heavy strain would be put on the cylinder and valves, due to the momentum of this moving water. To prevent this undue strain, a check valve is placed at (C_1), opening upward, so that, if from such a cause the pressure below the piston becomes abnormal, this valve is lifted, and some of the water is discharged into the circulating pipe against the pressure of the supply. Small check valves are also placed on the discharge pipe, and on the main piston. The former is for the admission of air, when stopping the car, behind the column of water passing through the discharge pipe. The check valve in the main piston is to allow any air that may have collected beneath the piston to pass upward through this valve to the top of the main cylinder, where it may be relased from time to time by an air cock (C_2). The pressure of air beneath the piston is very objectionable, since it causes a most disagreeable surging of the car when stopping. It will be noticed that there are two aprons or followers on the main piston. These serve the purpose of gradually closing the valve ports as the piston reaches the end of its travel, either at the top or bottom of the cylinder, and allows the piston to gradually cushion

itself on the enclosed water. These aprons also serve as a safety device, for if from any cause the car should get beyond control in either ascending or descending, it would come to an easy stop at the limit of its travel.

It is customary to balance part of the weight of the car and live load by means of counter weights. This principle of counter weighting is very important and is employed with nearly all forms of elevators. As the weight of the counterweight approaches that

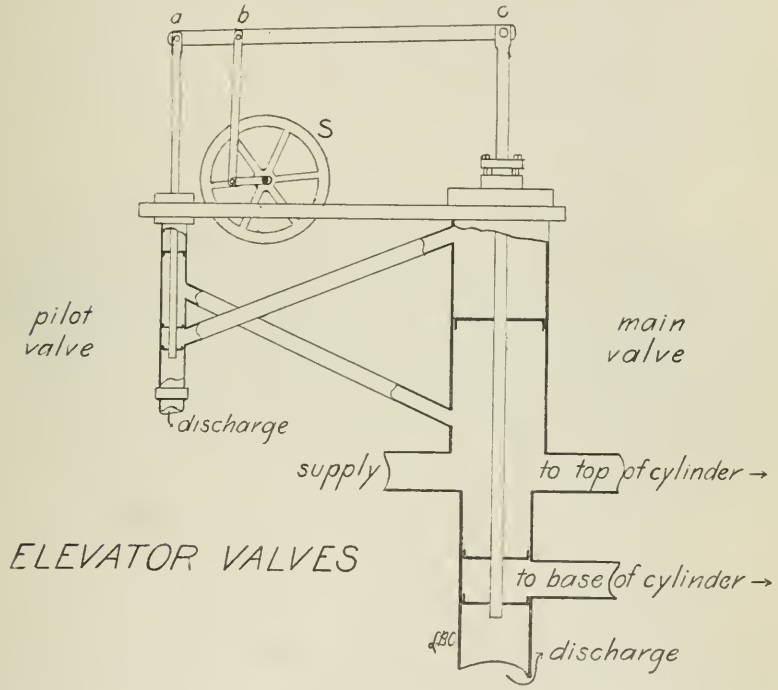


FIG. 3

of the car plus the live load, the resultant load to be lifted becomes less, and less powerful hoisting machines are required. Conversely, however, the total friction is increased, and besides this the inertia of the whole system is nearly doubled, which is an important consideration where rapid starts and stops are desired. In practice it has been found best to counterbalance the car for one-half to three-quarters of the maximum load.

In order to obtain a more delicate control of the elevator than is given by the valve already described, a special valve is employed as illustrated in the diagram, Fig. 3. In this case the controlling sheave (*S*) operates a small "pilot valve," which in turn operates the main valve by hydraulic pressure. The upper valve cup of the main valve is made a little greater in diameter than the two lower valve cups. If then the water above the upper cup is free to discharge, the difference in pressure on the upper and lower valve cups will cause the valve piston to rise. If however the pressure of the supply is allowed to act on both surfaces of the upper valve cup, the unbalanced pressure on the lower cup will cause the valve piston to be lowered. In either event the motion of the main valve is limited by the horizontal lever connecting the main and pilot valve rods with the controlling sheave.

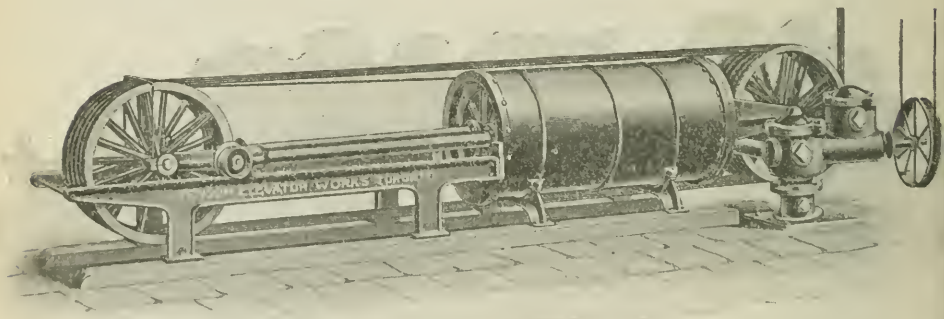


Fig. 4.—Horizontal Hydraulic Elevator.

There is another form of these multiple sheave hydraulic elevators, Fig. 4, which differs from the vertical type in that the main cylinder is placed horizontally. Owing to limited floor space the cylinders of these horizontal machines are made much shorter than the vertical cylinders, and in order to develop the necessary car speed are made of greater diameter, and have from six to twenty multiplying sheaves. In comparing the relative advantages of the horizontal and vertical types of these elevators, as important factor is the pressure of the supply water. Where the supply is obtained from the city mains or other low pressure source, the effective pressure at the top of a long vertical cylinder may be small, and the horizontal

cylinder machine has the advantage. The vertical type is however the most popular form due to the smaller floor space required, and also the fact that the length of cable and consequently the amount of stretch is less than with the horizontal elevators.

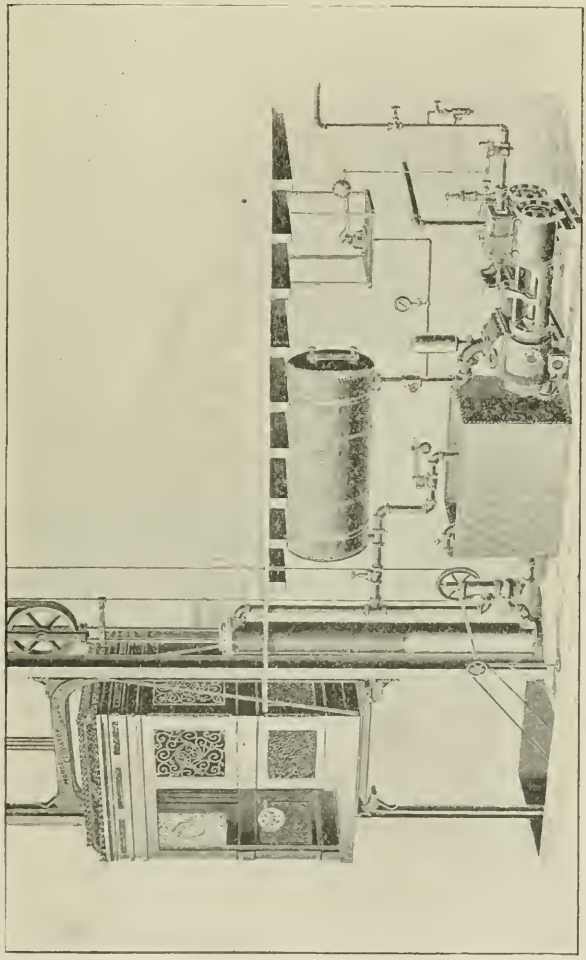


Fig. 5.—Pumping Plant.

The power necessary for the operation of hydraulic elevators may be obtained by a number of methods. The simplest and perhaps the most economical way in the case of very small plants is to

use the water pressure from the city mains. The pressure thus available in most cities and towns is about sixty to ninety pounds per sq. in. In the case of long travel, high speed elevators, especially where there are several elevators in constant use throughout the building, the quality of water used and discharged to the drain with this method makes it very costly. The standard practice in operating hydraulic elevators is by means of pumps in connection with either elevated or compression tanks. In these methods the same water is used over and over again, only sufficient water being added to the system as required to take the place of water lost by evaporation or small leakages. The general arrangement of such a plant is given in Fig. 5. The supply pipe to the elevator is brought from the lower portion of the pressure tank, which is strongly built of boiler plate and kept about two-thirds filled with water. The air enclosed in the upper portion of this tank is kept under a pressure of from 100 to 300 pounds per sq. in. Higher pressures than these are sometimes employed, but the strain on the valves is excessive and accidents are very liable to occur.

When the pressure in the tank falls, owing to the water supplied to the main cylinder on an upward trip of the car, an equal quantity of water is pumped into this tank from the discharge tank. This is done automatically by means of some form of regulating valve placed in the steam supply pipe to the pump. The valve is connected to the pressure tank by small piping, and when the pressure in the tank is up to the normal, this pressure acting on a diaphragm in the regulating valve keeps the steam supply pipe closed. When however the pressure drops, the throttle valve in the steam pipe is opened, and the pump continues to act till the pressure is again raised to the normal value.

There are several methods of operating pumps for hydraulic elevators aside from the use of steam. A common method consists in driving the pump by means of an electric motor, either direct connected or by belting. In some systems a starting rheostat is used controlled by a regulating valve connected with the pressure tank, such that the motor runs only when the pressure is low. In other cases the motor is allowed to run continuously, and when the pressure in the tank is up to the normal, an automatic valve opens a by pass around the pump. As the pump now simply causes a circulation of water around this by pass, the load on the motor is small.

ELECTRIC ELEVATORS.

The application of electricity to elevator service dates back to the beginning of the commercial development of the electric motor. These first electric elevators consisted of a motor belted to a belt

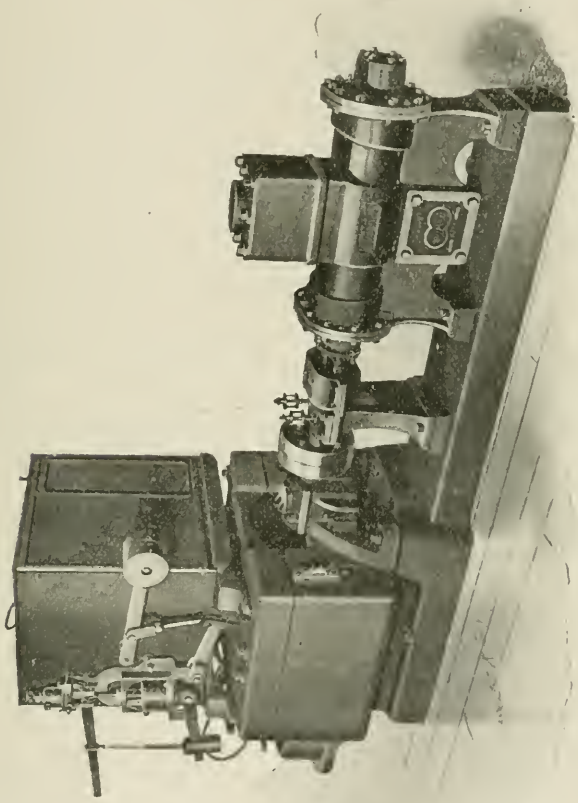


FIG. 5A.—"QUIMBY" SCREW PUMP DRIVEN BY ELECTRIC MOTOR.

driven elevator and allowed to run continuously, all control of the elevator being accomplished by means of the belt shifter and brake. In these early installations it was not considered feasible to start the motor under load, but when during the development of the

trolley, the successful operation of the direct connected motor became apparent, this principle was soon applied to elevator work. A diagram is given, Fig. 6, which shews the operation of a belt driven elevator. In all these belt driven machines the control of the elevator is effected by shipper ropes, and when operated by an electric motor a starting switch is usually connected to the shipper rope. There are a great many styles of these starting switches and rheostats, the one shewn in the figure however is a common type. On closing the shipper rope switch, either for an up or a down start, a magnetic clutch in the motor starter throws the arm of the rheostat in contact with a revolving worm, which causes the armature resistance in the rheostat to be gradually cut out. When this resistance is all out further rotation of the arm is prevented by the slipping of the clutch. Other forms of motor starters are operated by means of a solenoid, a gradual motion being obtained by the use of a dash pot.

In all belt shifting, belt driven elevators, economy is gained by the use of ordinary high speed, shunt wound motors, and as the motor is allowed to come wholly or partly up to speed before the load is applied, no great rush of current occurs at the moment of starting. The disadvantage, however, of these elevators is the jerky start caused by shifting the belt after the motor has attained a certain speed.

The type of electric elevator which is in most common use is shewn diagramatically in Fig. 7, in which the motor is direct connected to the hoisting drum. It will be noticed that in nearly all these drum machines the power is transmitted to the drum by means of a worm and worm wheel. The use of this combination in place of simple spur gearing, is due to the noise of the latter, and also to the jerky motion given to the car by spur gearing unless very carefully set. There is also difficulty with the latter in making accurate stops, and greater danger of the motion of the machine being reversed by an overload on the car. Though the use of the screw and worm wheel would not seem at first to be as efficient as spur gearing, yet it must be remembered that in place of a single reduction of speed in the case of the former, two or three reductions by spur gearing would be necessary; and the total friction losses might be much greater than in the case of a single worm and worm wheel. By the use of a specially cut worm and wheel the efficiency of the combination may be raised to about 65 to 75 per cent. It is customary

in order to ensure the best operation of the worm and wheel to enclose both in an iron casing which is kept partially filled with oil.

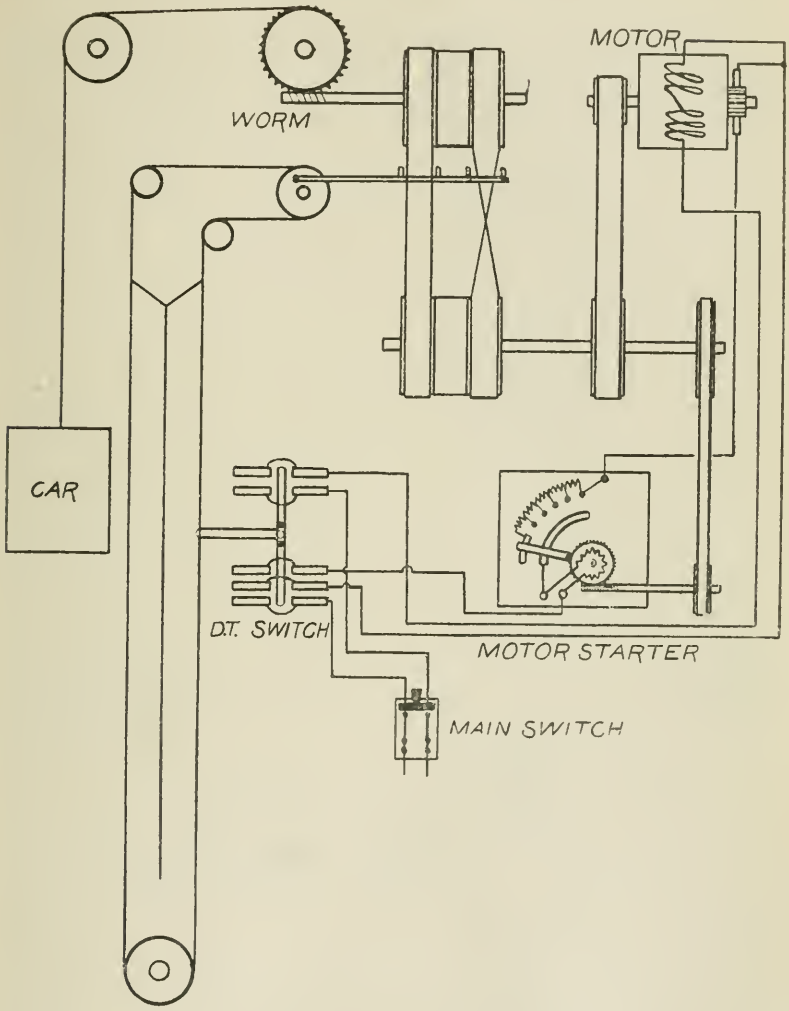


Fig. 6.—Belt Driven Electric Elevator.

In some machines, as shewn in the figure, two interlocking worm wheels are used in tandem. This method is adopted in order to prevent the heavy end thrust produced by a single screw and worm

wheel. This figure shews the usual method adopted in counterweighting drum elevators. Only part of the counterweight is connected to the car, or in case of a small load on the car the hoisting cable may

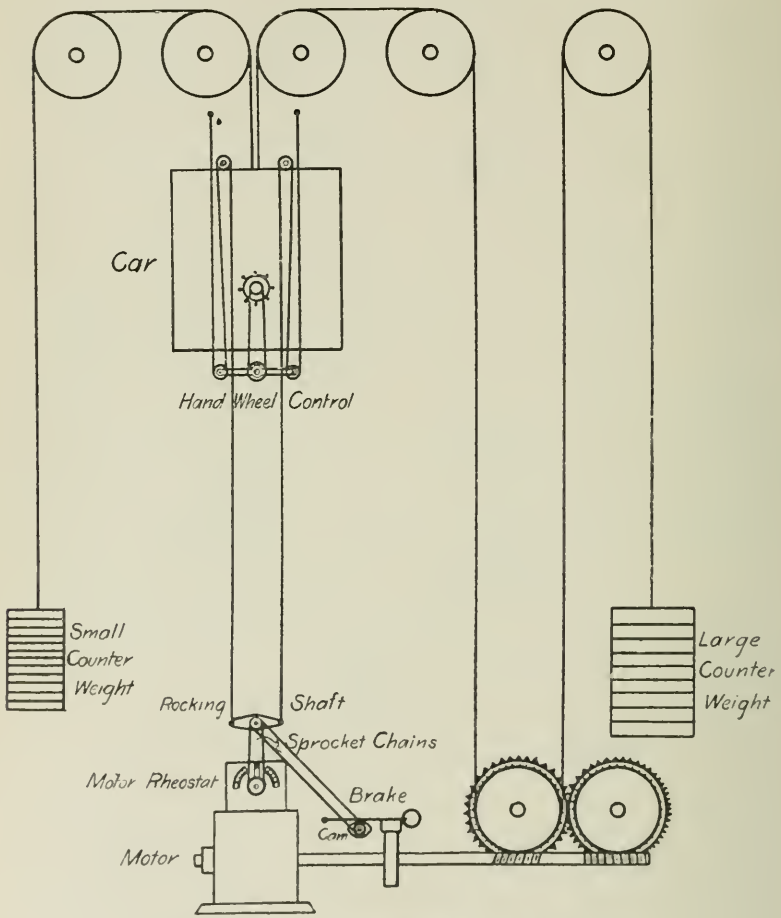


Fig. 7.—Direct Connected Electric Elevator.

become slack, which is an element of danger. On this account the greater portion of the counterweight is hung from the winding drum. In ordinary practice, the small car counterweight is made to counterbalance two-thirds of the weight of the car unloaded, while the large

or drum counterweight is of sufficient weight to balance the remaining weight of the car plus the average load.

There are several methods, both mechanical and electrical, of controlling the motor from the moving car. One of the commonest, the hand wheel mechanical control, is illustrated in the figure. The hand wheel in the car is connected by a sprocket chain to a lever beneath the floor of the car. Starting from fixed points near the top of the shaft, two flexible steel cables pass down the shaft, around two pulleys on the end of this lever, and up to and over two pulleys on the top of the car, after which they descend to the basement and are fastened at either end of a rocking shaft. In controlling the motor from this rocking shaft many ingenious forms of mechanism in the shape of levers, cams, toggle joints, etc., are employed by different manufacturers.

For the high speeds and long lifts met with in the taller office buildings, a special form of electric elevator has been developed, on the principle of its rival, the hydraulic multiple sheave elevator. In this case, instead of separating the multiplying sheaves by hydraulic pressure, the necessary thrust is obtained by converting the high angular velocity of the motor into a slow but powerful linear motion, by means of a screw and sliding nut. Like the hydraulic machines, these elevators are built in both the horizontal and vertical types. A diagram, Fig. 8, is given showing the general arrangement of one of these vertical elevators. Where a high ratio of speed is required, such as for instance fourteen to one, it is customary to get half the ratio, i.e., seven to one, by means of the multiplying sheaves on the machine itself, and to get the remaining ratio by means of a travelling counterweight, as indicated in the figure. Where the height of the elevator shaft is great, the weight of hoisting cable passing down the shaft to the car, will cause a great variation of the load and the speed of the car, as it travels up or down the shaft. In order to counteract this effect, a counterbalancing chain is employed, anchored at one end to a suitable point in the shaft, and at the other end to either the car or the travelling counterweight.

The efficient operation of these elevators depends, upon perhaps more than anything else, the construction of the screw and sliding nut, a section of which is given in Fig. 9. The screw is always in tension, and is so cut that the ball bearing surface is perpendicular

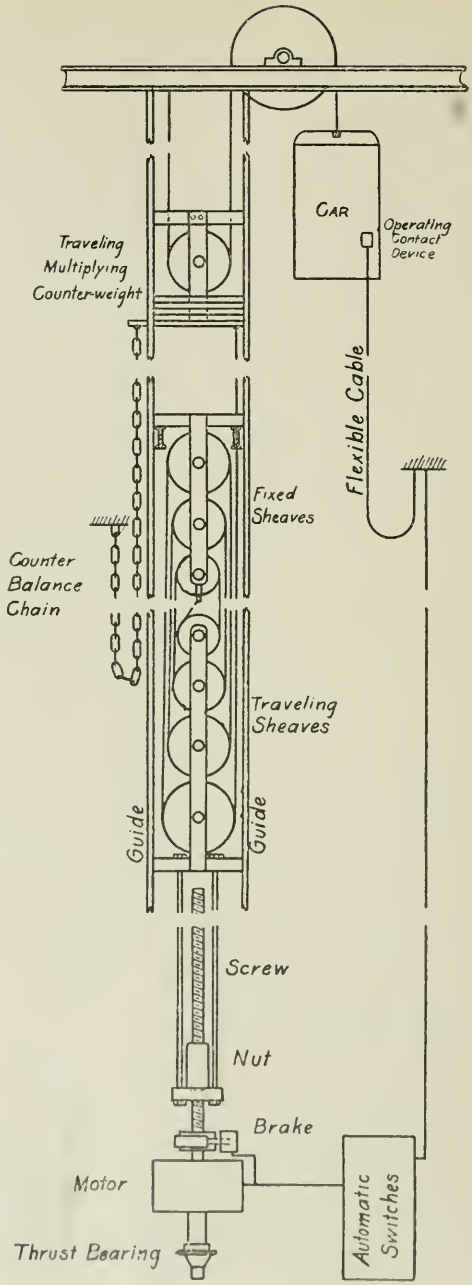


FIG. 8.—MULTIPLE SHEAVE ELECTRIC ELEVATOR.

to the axis of the screw. A return channel is provided in the nut, such that as the balls roll out at one end they are carried around to the other end of the nut. This nut is hardened, but the screw, which is made of a forged bar of high carbon steel, is left unhardened as it is found that the rolling compression to which it is subjected by the steel balls, after a short time produces an exceedingly hard surface. At the end of the nut next to the crosshead is an additional or safety nut. This nut contains no balls, and has its threads held apart from those of the main screw by means of two small springs in the nut itself. The sliding nut is in contact with the crosshead by a conical seat, and normally the friction between these two, due to the pressure between them, is sufficient to keep the nut from turning. However if the hoisting cables should slacken from any cause, this pressure decreases and the springs on the safety nut cause it to bind on the shaft, and as the nut now revolves with the screw, no motion is given to the crosshead.

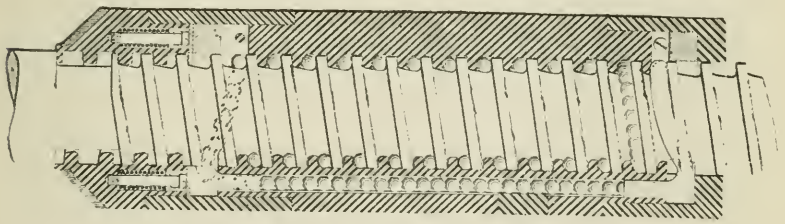


Fig. 9.—Section of Screw and Sliding Nut.

In all drum-winding electric elevators the motor operates in both hoisting and lowering. In the case of the screw and sliding nut machines however, current is used only in hoisting, the car descending by its own weight.

The type of motor to be employed in these direct connected elevators is of prime importance. Since the motor must bring the loaded car up to maximum speed as rapidly as smoothness will allow, it must possess a powerful starting torque. The motors used for this work are usually direct current, operating at low speeds of about six hundred revolutions per minute. In the simpler machines a shunt field is usually employed, but in many cases the field winding is compound, having a starting series coil, and a shunt winding which serves to steady the field. Where, as is generally the case, current

is used in the motor both in hoisting and lowering, reversing devices must be used. Where current is used only when the car is going up, the speed when descending must be checked by means of some form of brake. In this case the shunt field is left connected across the mains, and since the motor now operates as a dynamo, the speed may be controlled by short circuiting the armature through an adjustible resistance. The various switches, armature rheostat, and brake are in some machines all operated directly by levers or sprocket chains from the rocking shaft. In other cases the starting devices are operated partly mechanically, and partly electrically, while in many machines all control is effected electrically from an operating contact device in the car. In this case all the switches, etc., are operated from solenoids, and the armature rheostats either by solenoids or by means of a small pilot motor.

In private residences and some other cases where it is undesirable to employ an elevator boy, a special system of control is sometimes used. There are several of these automatic elevator systems, in all of which drum machines are used with solenoid control. In the "push button" system, a single push button is used at each landing. The pressure of any button starts the car, and on reaching that floor a car switch is tripped which stops the car. The car is controlled from the inside in the same manner as in ordinary systems. In another system a three-point switch is placed at each landing, and also in the car. Placing the switch, on a certain landing, at the "up" or "down" contact, starts the car in this direction, and on reaching the required floor the car is stopped by placing the switch at the "stop" contact. The control from the car itself is effected in the same manner. In both these systems while any switch is in use all the others are automatically disconnected, so that no interference from them is possible. It is also customary to include in the main circuit, a small switch placed at each elevator gate. These switches are all connected in series, so that if from any cause any gate should be left open, the elevator will not operate.

Besides these automatic systems, there is an important variable voltage method of control employed in many high class elevator installations. In this system, instead of controlling the motor by rheostats from constant potential mains, the current to the motor is varied by varying the voltage supplied. This has been done

in a few instances by the use of storage batteries, the voltage being determined by the number of cells connected in series.

In the ordinary, or Leonard variable voltage system, a separate generator is used for each elevator motor, the speed of the motor being controlled by changing the resistance in circuit with the generator field. The elevator machine is of the ordinary drum type, the motor being shunt wound. The field winding is connected permanently to the supply mains while the armature brushes are connected directly to those of the dynamo. The terminals of the field winding of the dynamo (also shunt wound) are carried by a flexible cable to a field rheostat placed in the car, to which is also brought the supply mains. The direction of rotation, and speed of the motor is then controlled by the sense, and strength of current, respectively, sent through the generator field winding.

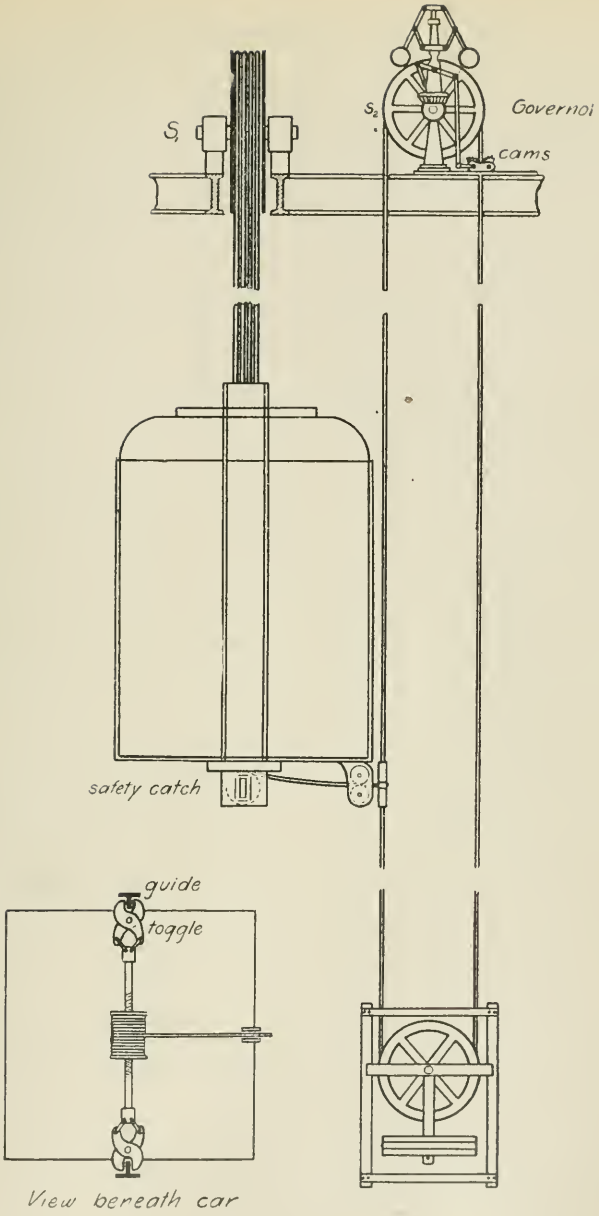
The great advantage derived by the use of this system is due to the fact that it allows an ideal start or stop, and gives a perfect control over the speed of the motor. The system is also economical in operation since owing to the small dynamo field current required, practically no power is wasted in starting or regulating rheostats. On the other hand, the dynamo must be of ample size to carry the maximum load placed on the motor, and as the average load is usually only about one-fifth of the maximum, the generator is running at low efficiency. The chief defect however in this system is the capital outlay necessitated by the use of a separate generator for each motor.

The excellence of any type of elevator is judged by its (1) Safety, (2) Reliability, (3) Economy in Operation, (4) Compactness, (5) First Cost.

Safety.—Without doubt safety is the question of prime importance in elevator design. From the very nature of elevator service, the widely varying loads, the rapid starts and stops, and the disaster which may result from the failure of the working parts, great care should be taken in the construction of such machinery, and a liberal factor of safety allowed. In order that absolute safety may be assured, provision must be made for preventing a fall in case of the cable stretching or breaking, for stopping the car in case of excessive speed or at its limits of travel, and for holding the car stationary in case the motive power is cut off.

Of the safety apparatus necessary for this work, part is placed on the machine and part on the car. In the case of hydraulic elevators, the limit stops consist of an apron on the piston or other means of closing the ports. In the case of electric elevators, a switch is opened at the limits of travel, which cuts off the power and allows the magnetic brake to act, or, on some machines, a sliding nut at the limits of travel causes the controlling sheave to be thrown to the stop position. The magnetic brakes used with electric elevators consist of a steel band, or bands, lined on the inside with wood or leather, and encircling the brake pulley. This band is normally held strongly against the pulley by means of a spring. In starting the car a current is sent round a magnet or solenoid which counteracts the effect of the spring, and releases the brake. This magnet or solenoid is placed in the main circuit to the motor, and the very operation of cutting off the current to stop the car, or any failure in the supply mains, at once applies the brake. Slack cable devices are sometimes placed on the car or at the machine. A common form of the latter consists of a lever which bears against the cables as they leave the main drum. In case the cable slackens, this lever is allowed to spring over, and by opening a switch, or otherwise, applies the brake. The safety speed stops may consist either of a centrifugal governor on the machine which operates the brake directly, or safety grips on the car operated by a centrifugal governor in the shaft. A standard form of the latter is shewn in Fig. 10. Beneath the floor of the car is placed a small drum supported at each end on a short rod connected to a safety clutch through a toggle joint. The rotation of the drum on these two rods, by means of a right and left hand screw, draws the rod together and causes the safety grips to grip the guides. The free end of the rope wound on this drum is fastened to a continuous vertical rope, which passes freely around two pulleys, one at the top, and one at the bottom of the shaft. The upper pulley operates a centrifugal governor, and in case the speed of the car exceeds a certain limit, this governor lifts a lever, which causes the cams to grip the rope, holding it stationary. As the car continues to travel, the rope on the drum beneath the car is rapidly unwound, which operates the safety grips and stops the car.

A safety precaution, which has been adopted in several instances, is to tightly enclose the lower story of the elevator shaft, such that



SAFETY DEVICES

Fig. 10.

in case of the car falling, the air partially shut in below the car may act as an air cushion and bring the car to an easy stop. A few exciting trials have been made by allowing the car, containing baskets of eggs, etc., to drop freely the whole length of the shaft. Though in these tests no eggs were broken, still the ordinary mortal would prefer to depend for safety on this system only after all the ordinary devices had failed.

Reliability.—This comes next in importance to the question of safety. The necessity of shutting down an elevator frequently for repairs is not only expensive, but may seriously interfere with the accommodation of the building and will lower its value. Hydraulic, have perhaps the advantage over electric elevators in this respect, as the working parts are few and substantial. The only parts requiring renewals are chiefly the valve cups, and the packing of the piston, and this is only necessary at long intervals. Electric elevators are much more complicated, but on the other hand they are generally run independent of one another, so that an accident to any machine affects that elevator only. In the case of hydraulic elevators, all of which in one building are usually supplied from a single large pressure tank, any accident to the supply pumps, etc., will cause the shutting down of the whole plant.

Economy in Operation.—This is perhaps the most hotly contested question between the advocates of hydraulic and electric elevators. In the case of hydraulic elevators, the work expended in lifting the car, is as much when the car is empty, as when fully loaded, since in each case the water at the constant pressure of the pressure tank acts through the same volume of the cylinder. The power consumed by the motor in an electric elevator varies directly with the load. When starting the elevator however, and overcrowding the inertia of the moving parts, there is an abnormal rush of current, and in elevator service the starts and stops are so frequent that the average current used by the motor is much greater than that simply due to the load. On the other hand, certain high grade electric elevators will, when the car is descending, return current to the line, and the total current used by a bank of elevators in a building may be surprisingly small. One of the greatest advantages of hydraulic elevators is the storage of energy possible by means of the pressure tank. That is, the constant operation of one, or more small pumps, may be capable of supplying power to a large system of elevators operating intermittently.

Conversely, however, the efficiency of the ordinary steam pumps is very low compared to the general high efficiency of electrical machinery. In some of the later hydraulic elevator plants fly-wheel pumps are used, which enable the steam to be used expansively, thus obtaining a higher efficiency.

Compactness.—In this respect and also in regard to cleanliness the electric elevator is pre-eminent. In many elevators of this type all the operating machinery can be placed in the space at the bottom of the elevator shaft.

First Cost.—The price of both hydraulic and electric elevators varies widely, according to the grade of machine required, the locality, and other considerations. For a first class plant in either case however the difference in cost for either system is small.

Conclusion.—The best form of elevator to install in any case depends entirely on the conditions governing that plant. For small plants in a locality where electricity may be obtained at a reasonable figure from the central station, this system is the one usually employed. In the case of medium and large-sized installations, the choice of elevators is determined by the class of elevator service required, by the cost of electric and hydraulic power from the street mains, the cost of coal, whether or not a lighting or steam heating plant is used in the building and other considerations. Since the elevator forms an integral part of the finished building and cannot be changed except at great expense, a careful preliminary study of the conditions involved should be made in each case. This is essential in order that the elevator after erection shall prove the most suitable for the purpose.

CIRCULATION IN WATER TUBE BOILERS.

W. Monds, Grad. S. P. S.

With the increasing tendency towards the use of high-pressure steam, especially in the navy and marine, has come the introduction of the water-tube boiler with its numerous claims to safety and to economy in space and fuel. Doubtless these claims are greatly exaggerated, but still this type of steam generator seems to possess sufficient advantages to enable us to point to it as unmistakably the boiler of the future. "Efficient circulation" is the one point which is generally regarded as essential to the successful working of these tubulous boilers, and unless a manufacturer can shown on paper at least, that his boiler has been designed to provide a definite course for the circulating water his output, in accordance with the law of supply and demand, is apt to be exceedingly small.

This paper has been prepared with the object of discussing a few of the main points in connection with circulation and to show the methods adopted in dealing with the subject.

ADVANTAGES OF CIRCULATION.

It is a well-known fact that when water containing certain salts is heated to the temperatures which obtain in ordinary boiler practice the salts are precipitated. An example of this may be seen any day by examining the water coming from the ordinary hot-water boilers in our private houses, where, on account of the pressure, a high boiling point exists. The water will appear quite milky and this appearance increases with a rise in temperature. Now if this precipitation takes place in one of the tubes of a boiler, the salts if left unhindered will soon coat the inside of the tube and burn into a hard scale, which will in a short time decrease the efficiency of the heating surface as much

as twenty-five per cent. But this scale soon becomes a source of absolute danger, for the tube unable to transmit its heat to the water becomes red-hot and possibly bursts, allowing the scalding steam and water to rush out through the furnace and ash-pit doors. Accidents such as this are generally disastrous to the attendants especially on board ship, where the stokers are unable to escape from their air-tight stokeholds. Sometimes it happens that when the tube becomes very hot the different rates of expansion of iron and scale cause the latter to crack and peel off; this leaves the surface, now red-hot, once more in contact with the water, the result is that steam is generated so rapidly that the pressure in the boiler is raised sufficiently to cause rupture at some weak point, and disaster follows.

It is, then, very important to impede the formation of scale as much as possible, and evidently the best way to do this is to keep the precipitated particles in constant motion while within the tube and provide a settling chamber whither they may be carried by the circulation of the water, and where they may drop to the bottom away from the heat of the furnace. These mud-drums, as they are called, must of course be sufficiently large to make the velocity of the water very small while passing through them, in order to allow time for the scale and mud to drop.

Another very frequent accident through lack of circulation is caused by the formation of "pockets" of steam. The water is forced away from portions of the tube by the generation of large steam bubbles which cling to the sides, and the tube becoming white-hot gives way.

One of the greatest troubles with water-tube boilers has been the unequal expansion of the different parts, resulting in very serious strains on the joints, and consequent troublesome leaks. All this is of course due to unequal temperatures caused by a deficient circulation, for water is a poor conductor and only supplies heat by convection.

HOW CIRCULATION IS OBTAINED.

Nearly all the successful tubulous boilers are of the same general type, that is they consist of a bent tube in the shape of the letter U, which acts as the generator, surmounted by a reservoir for steam and water (Fig. 1.). If the fluid in one leg of the tube be of less density

than that in the other, the columns are not evenly balanced and consequently there will be a flow of the liquid from the denser to the lighter side in an attempt to restore equilibrium. Now in a boiler the difference in density is maintained continuously by the formation of steam bubbles in the lighter side, so that equilibrium is never attained and the phenomenon of circulation results.

There has been considerable discussion as to whether or not these bubbles really decrease the density of the fluid. Some writers have claimed that we might just as well anchor a string of corks in

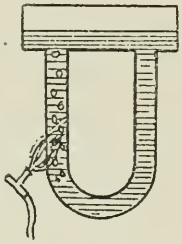


Fig. 1

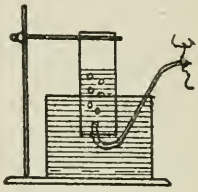


Fig. 2

the tube and then we would have circulation from cold water. But it is just this anchoring which causes the difference in the two cases, for the bubbles are free to move upward. The simple fact of being compelled to anchor the corks shows that a downward pull must be exerted on them, and this force transferred to the water is necessary to preserve equilibrium. It may be easily shown that the pull downwards on the corks must be equal to the weight of water displaced.

A very simple experiment may be made to show that a mingled column of gas and water is lighter than an equal column of solid water. Fig. (2) is self-explanatory; it shows an outer glass vessel filled to the brim with water, and an ordinary lamp chimney suspended in it. Now if air be blown up through the chimney a mingled column of air and water will rise in it much higher than the edge of the outer vessel, and yet no water will run over the side. This shows that the heads in both vessels though of different heights yet balance each other.

DIRECTION OF CIRCULATION.

The general aim of manufacturers has been to have bundles of tubes acting as uptakes placed in the hottest parts of the furnace, and to have these tubes supplied by downtakes which are shielded from the heat as much as possible. In many cases the downtakes are well lagged and carried outside the furnace altogether.

A series of very interesting experiments was arranged by Mr. Yarrow of the celebrated ship-building firm, and Mr. Hiram Maxim

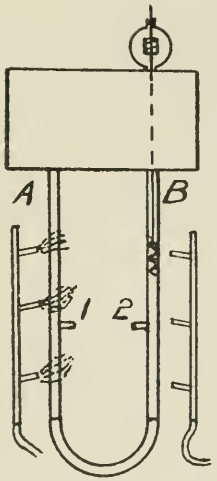


Fig. 3

of machine-gun fame. to show that special downcomers are not a necessity, and if they are used they should be placed within the furnace

Fig. (3) represents in diagramatic form the improved apparatus used by these gentlemen. It consists of an upper drum or reservoir from which depend two glass tubes *A* and *B*, connected at their lower extremities by a copper bend. On each side are placed three Bunsen burners capable of separate regulation. A small screw propeller attached to a shaft is placed in the tube *B*, while the shaft extends up through the two bearings shown in the sketch. Any motion of the water will cause the propeller to turn, and the direction and

speed of the motion may be ascertained by observations on the indicator above the drum.

The burners on the side *A* were first lighted one by one, and soon a circulation of the water from *B* to *A* was set up, which became quite vigorous when the boiling-point was reached. After the water had been boiling steadily for some time the speed of the shaft was noted, and then the burners on the tube *B* were lighted. Instead of stopping the circulation already existing it was found that the motion of the water continued in the same direction as before, and with a greatly increased velocity.

Next, the flame was entirely shut off the tube *A* and applied to *B* only: the result was a considerable decrease in the velocity, as might be expected, but the current still continued quite vigorously in the original direction from *B* to *A*.

The conclusions drawn from the experiment by Mr. Yarrow were that the direction of circulation depends only on the direction in which it gets started, and not on the point of the application of the heat, and that the amount of circulation varies directly with the total heat added to the water.

A similar experiment was made by taking away the burners and connecting a compressed air tank to the cocks in the tubes at (1) and (2). Air was first let in at (1), and as it passed up the tube *A* it set up a circulation from *B* to *A*. Then air was allowed to enter the tube *B* at (2), but the bubbles, instead of rising, followed the course of the moving water from *B* to *A*, and greatly accelerated its velocity. When no air was allowed to enter at (1) the current, though decreased in velocity, showed no tendency to reverse, no matter how long air passed in through (2).

In the next experiment (Fig. 4), a similar apparatus was used, but with the addition of a third tube, which was intended to represent a downcomer in the Normand type of boiler. *A* and *B* were heated simultaneously and an upward circulation started in both, while a downward current took place in *C*. When the flow became steady *C* was heated, and immediately a great increase in velocity took place in all the tubes, while the direction of circulation remained as before. This result showed that if separate downcomers are used they should always be placed inside the furnace, where they may receive heat.

But the following experiment showed conclusively that in boilers of the Yarrow, Normand and similar designs, separate downcomers are not a necessity, and may be dispensed with, and at the same time no injury to the efficiency of the boiler will result. In Fig. (5) a number of tubes are shown connecting upper and lower chambers precisely as in actual boilers. The side *D* was heated first, and the heat allowed to pass through to *E*, and in every case it was found that the circulation was upward in the first two or three tubes and downwards in the outer ones.

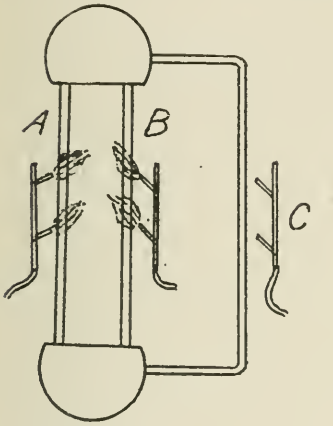


Fig. 4

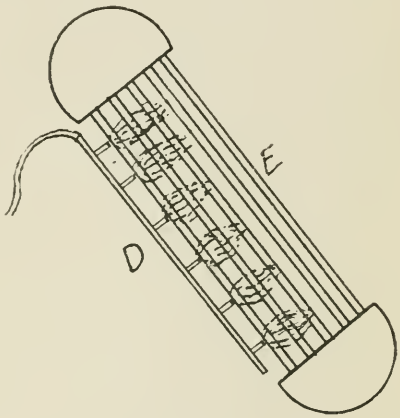


Fig. 5

As this action occurred no matter whether special downtakes were provided or not, Messrs. Yarrow have discarded downtakes altogether, and find that they lose nothing by so doing.

If the apparatus in Fig. (5) be inclined at a less angle to the horizontal than that shown, we will have an arrangement identical with the bundle of tubes connecting two headers or water-legs, as used in such boilers as the Babcock & Wilcox, the Heine and other prominent makes, while the overhead drums of these types may be said to take the place of external downcomers. Deductions from Mr. Yarrow's work, confirmed by experiments by other authorities, show that some of the water in the front headers enters the upper rows of tubes, flows toward the rear of the boiler and once more helps to supply the forward current in the lower rows of tubes.

QUANTITY OF WATER CIRCULATED.

In boilers such as the Thorneycroft, which have "above-water" delivery, direct measurement of the circulation, has been made by the use of weirs, but with the ordinary type of "drowned" delivery such measurements are impossible, and recourse has been taken to mathematical calculations. Formulæ for the velocity in the tubes form the basis of all these calculations, and while the methods employed to obtain them are somewhat ingenious, results are so divergent that no practical use can be made of them.

SOME NOTES ON BRIDGE DRAFTING.

R. K. Palmer, B. S. Univ. of Mich.

There are in general two classes of engineers, or perhaps I should say two ends to engineering, the consulting engineer's end and the contracting engineer's end. The consulting engineer's knowledge is often general rather than particular, and rightly so because this enables him to take a bird's eye view as it were, of the entire work, and to see that each part bears a proper relation to every other part.

The contracting engineer has to face a different problem. He finds the work laid out in a general way and it becomes his duty to carry it forward and to look to all the processes in its manufacture to the smallest details. He must, in short, produce the work and on a paying basis. The former may get his knowledge largely from books, current publications, and from good specifications bearing on the subject, but the contracting engineer must be familiar with these and more, he must know all the little kinks and turns that never see the printed page, and can only be learned by association with those who have been long in that particular line.

It may have occurred to you that engineers are not made in our engineering schools, or perhaps I should say they are not completed there.

Neither are they made outside of our schools, for however expert a man might become with rules of thumb, still, he does not understand why he does things in a certain way and is therefore liable to endanger other peoples' lives. Our friends the medical men are enabled to get all that is desirable for practice in the medical colleges and the hospitals attached thereto, but, from the nature of things, the engineering student must bide his time to get at some actual work instead of imaginary cases.

I remember very distinctly that at the time I left the University I was crammed with theory to the exclusion of most that was practical, and, at that time, theory of itself was not of a great deal of use, for I got no chance to use it. I had a very vague idea of what occurred in a bridge works and my only excuse for taking your time is that I may tell those who are in a like position, something of how work is done there.

Most public works, and structural works in general, have a consulting engineer in charge of the work, who specifies more or less particularly just what the work shall be. In the case of a bridge he may just give the span, the loading, and such other items as the location demands, and the several bridge companies will submit specific designs and prices. Then, again, he may submit the complete design and ask for prices. Or yet again, he may submit detail drawings, although very rarely, as few men will make drawings that will satisfy a bridge company for actual manufacture.

In submitting prices the company must have a very close estimate of the necessary material to complete the structure, together with information of the probable difficulty of erection, and the location which involves the cost of transportation. Other considerations are the amount of work required in the shop and in the drawing office.

We will suppose we have received the contract for building some bridge. By this time, of course, we will have had the stress sheets and the general design completed. The next thing is to order the necessary material from the rolling mills, and to do this we must make very careful layouts, so that we can order our material just of sufficient size and no more—for excess involves waste, and hence, loss. These layouts are just pencil drawings on brown paper, showing the connections of the different members, and vary in scale from 1 in. to the foot to 3 in. to the foot.

Having made these layouts and calculated all rivets, pins and such things, we are ready to write what is called an original bill. This bill involves every piece of metal that enters into the contract including rivets and bolts, and tells where each piece goes. Then from this bill is written the orders to the various mills that furnish the raw or finished parts. For instance, it might be advisable to get plates in Scotland and angles and other shapes at the Pittsburg

mills, owing, perhaps, to price, quality or time required to deliver the material. For the past few months it has been desirable to get plates in Scotland—the American mills being too crowded to execute orders in short enough time.

We now have all the necessary information to go ahead and make shop drawings, and this may be done at once, or a considerable time after—the information will keep. These shop drawings may save or break the company, and, likewise, save or break the necks of the people who travel across our bridge. Fortunately few bridges do go down—perhaps because the factor of safety is taken high. I may say just here that the term "factor of safety," is falling into disuse. The better practice is to state definitely the allowable working stresses per square inch of section, having regard to the kind and range of stress together with the frequency and suddenness of application. For instance if you were making a roof truss with nothing but the roof to support you have the constant load of the roof, together with the weight of the truss itself, and whatever loads might come, due to snow or wind, each coming on gradually, and at rather long intervals. Here the unit stress could go to 20,000 pounds per sq. in., or even 25,000 pounds per sq. in. without danger, but you would hardly proportion a railroad bridge with such unit stresses.

Now as to the making of the drawings—a thing which some of you gentlemen may get interested in some time or other. I can only say that the sole way to learn to draw is to go and draw and keep drawing something—you will draw bridges later. Generally in bridge offices the drawings are made by one man and checked by another. Of course a man coming from college is started with the simpler things, and what he learns he gets largely from the man who checks his drawings. Let me say here that if any of you gentlemen ever take up bridge work my advice is to get under a good checker, if you can, and do not kick and worry when your drawings come back to you pretty generally marked up. It has been done with a purpose, and if you observe some of those little points you will progress the faster. And remember that after the checker has finished your drawing and signed his name thereto, it is your drawing no longer for he alone is responsible for errors. Responsibility makes him more careful than lack of responsibility does you.

But let us come back to those drawings. You will agree with me, I think, when I say that a structure of whatever kind and for whatever purpose, is best designed when it is perfectly balanced throughout. In other words every part should be proportionately equal to every other part. Your fence will not hold much when the bars are down, even if it is a good fence. This matter of perfect balancing is the acme of the draftsman's art, for it certainly produces the best structures at least possible cost for material.

To this end we must see that all joints and splices are correct and adapted to the case in hand. Due regard should be given to the methods used in manufacture to determine how much we might increase the sections and weights in certain places in order to duplicate similar parts, thus reducing cost. That is to say, if the added cost of making a part different from a similar part is greater than the cost of the extra weight necessary to make them alike, then in general we would make those parts interchangeable. The added cost arises through additional drawings and templates, and the fact that the workmen have to spend more time in finding out what is wanted.

In making the drawings it is best, in general, to show the structure assembled, because less is left to the imagination, and besides it requires less drawing. In starting our drawing the centre lines should first be laid down and then the sections drawn, making centre lines of the bridge coincide with the centre of gravity lines of the members as far as possible. Very frequently rivet lines of angles are used instead of gravity lines and of course our structure is somewhat weakened. If there be much difference between the two it is considerably weakened. Sometimes the centre of gravity line of a top chord member is placed a short distance above the centre line to overcome the sag of the member due to its own bending moment, but this is a refinement that is hardly warranted for the centre of gravity lines of the chords in various panels seldom coincide any way. The result of this raising of the centre of gravity may be made clearer by referring to Figs. 1 and 2, Fig. 1 being when the centre of gravity and centre lines coincide, and Fig. 2 when the gravity line is raised. Fig. 2 is exaggerated.

As an example of the relative position of centre of gravity lines, and rivet lines, let us make two angles 6″ x 4″ x ⅜″ riveted in the usual way.

When placed like Fig. 3 it will be seen that the lines nearly coincide, and in this case we may use the rivet lines for centre lines. But when placed as in Fig. 4 the lines are separate, and we must not consider them coincident.

Having laid down the lines of our truss it behooves us to find out how it is to be shipped to its destination,—if to be carried on wagons and how far. The manner in which it is to be handled will determine the size of the pieces shipped—in other words it will locate the field connections. These must be known early because we will need to use perhaps 25 per cent. more rivets in a field joint than in a shop joint. The reason for this is that field rivets are not, and cannot be, as tightly driven as shop rivets under the air riveters.

Our top and bottom chords must be spliced if the section changes from panel to panel. If they are long they must be spliced anyway. The previous considerations will locate these splices, having a care to always make the splice on the side of the joint having the least stress. Compression members are usually brought to a tight fit at the splice by milling the ends, and in this case, only enough rivets are used to keep the members rigid, but if the joint be not planed, a full quota of rivets must be used with corresponding splice pieces to carry the stress.

Splices in tension members present a more complicated problem and we would do well to look more closely into it. Let us first observe the effect of putting rivet holes in a piece under tension. Quoting "Cooper's Specifications" for bridges we find, "The rupture of a riveted tension member is to be considered as equally probable, either through a transverse line of rivet holes or through a diagonal line of rivet holes where the net section does not exceed by 30 per cent. the net section along the transverse line."

Suppose we have a plate, say 11½ in. wide, with four lines of rivets, as shown in Fig. 6, and it is necessary that we so space the rivets that the total section be reduced by only two rivet holes. Let them come opposite each other on the line *a b*, our next rivets coming opposite each other on the line *c d*. It is necessary to determine the distance *a c* such that the net section on *a e g h f b*, shall be 30% in excess of the section on *a e f b*. For convenience of illustration let us use 25% instead of 30%. On laying it out we find *a c* must be about 4 inches. It happens in this case that if the rivet

be left out that the 4 inches still stands, but if f instead of h be dropped then this distance, $a\,c$, becomes $5\frac{3}{8}$ inches.

If f and h be dropped then to cut out one rivet the distance $a\,c$ becomes $5\frac{5}{8}$inches. If f and g be dropped then to cut out one rivet the distance becomes $7\frac{1}{3}$ inches, and on dropping e and f it becomes 4 inches. If g and h be dropped it becomes $8\frac{5}{8}$ inches, which is impracticable, and the wider the plate and farther apart the rivet lines the greater the distance becomes, because if the relative lengths of the hypothenuse to the side as the angle changes.

Suppose we apply this to an angle gauged as shown in Fig. 5, using a 6″ x 6″ angle. This may be conceived of as a bent plate, which can be again made flat, and we would have the plate we have chosen above, and the same combinations would give the same results.

To splice an angle removing but one rivet. Let us take an angle 6″ x 6″ x $\frac{1}{2}$″=5.75 sq. in. area. Deduct one hole for $\frac{7}{8}$″ diameter rivet = 5.25 □″ net. At 10,000 pounds per sq. in. this would stand. 52,500 pounds.

Bearing of $\frac{7}{8}$ dia. rivet on $\frac{1}{2}$″ metal @ 15,000 lbs. per sq. in.=6,500 lbs.
Shear of $\frac{7}{8}$ dia. rivet @ 7,500 " " =4,500 "

Dividing 52,500 by 4,500, the smaller of these rivet values gives 12, the number of rivets required, they being in single shear as shown in Fig. 7. After the first rivet in this case two holes may be deducted as the stress is lessened by the amount that passes in one rivet, hence the rivets near the centre on each side are closer together. Note that the end rivets are on the inside gauge lines, which lessens the spacing here. This follows from our previous consideration of the plate, and the manner of deducting rivet holes.

In general, tension members are so designed that all rivet holes that are likely to be needed may be deducted, and still leave the net section intact. In favor of this we can use shorter splices, thus saving material and run less risk of a bad arrangement of rivets. On the other hand our section has been increased by the amount cut out, and if the distance between splices is great the added weight may be worth considering. In very many existing structures this principle of splicing has been disregarded, and the true unit strains are much greater than was intended. So far as the writer knows

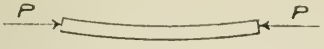


Fig. 1

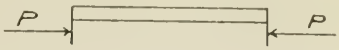


Fig. 2

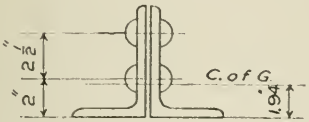


Fig. 3

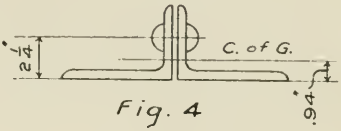


Fig. 4

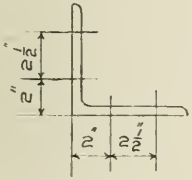


Fig 5

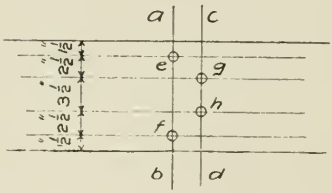


Fig 6

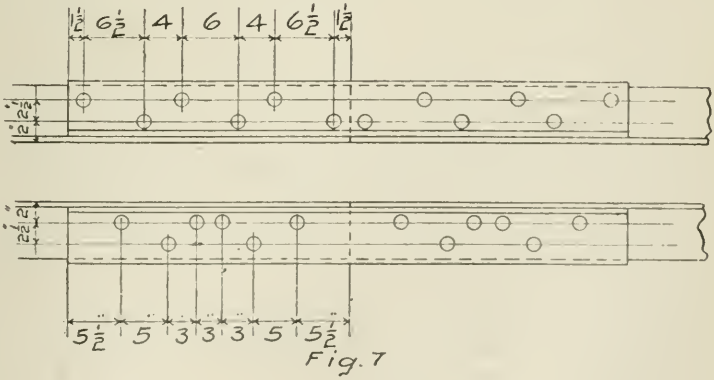


Fig. 7

no tests have been made to show how the plates and angles previously mentioned would break with the several arrangements of rivet holes. An investigation along this line would prove profitable to some one having a testing machine at hand and a thesis to write.

The making of practical working drawings for the bridge shop requires a knowledge of the part that each man plays from the beginning until the work is completed. After leaving the office the drawings first encounter the template maker, and the draughtsman must have a knowledge of the kind of template to be used and the manner of making it. He must see that his drawing has every dimension that will be needed to make the template for each individual piece, and nothing more, except the necessary information for the other portions of the shop. He must above all see that the plans are practicable. For instance, he must not require rivets to be driven in impossible places, as sometimes happens with the best of men. The method of erecting frequently decides the manner in which certain connections will be made, and the draughtsman must have his eye on the erector, so to speak, as well as the shop workmen.

The following will serve as hints to those who are just beginning to draw.

Give all general dimensions such as length over all, width, and clear head room, as well as the number of spans.

Look out for camber and see that the diagonal distances are correct.

Calculate pin sizes and see that eye bars are properly packed.

See that all slots are made to allow for expansion. Iron expands practically ⅛″ in 10′ 0″.

See that rivets are countersunk where necessary, check over all field holes and note that proper clearances have been allowed.

See that all rivets can be driven, bolts can be put in place and nuts turned.

See that filler plates are called for where necessary.

See that joints and ends to be planed are so marked.

Look out for rights and lefts.

See that laterals do not interfere with stringers or beams.

See that the rails will clear the rivets on the top of the floor-beams.

See that stringer bracing angles do not interfere with the ties.

See that eye bar heads clear the cover plates in the top chords and end posts, and calculate the bearing of the eye bars on the pins.

When two or more spans connect see that the ornamental iron work and name plates are at the extreme ends only.

See that general notes are complete *i.e.*, notes referring to painting, size of rivets and rivet holes, reaming and any general information necessary.

If bridge is on a grade see that the sole plates are properly beveled, and if the bridge is also on a skew note that the shoes at either end are some distance apart, measured along the centre line of the bridge, and hence the bridge seats on the same abutment are at different levels. This difference in level must be taken into consideration.

Where there are several thicknesses of plates packed together, it is customary to allow about $\frac{1}{32}$ of an inch to each plate to insure sufficient clearance to erect the work easily.

In the work of laying out bridges eternal vigilance is the price of accuracy, and accuracy is a thing most to be desired. Some men never can attain great accuracy, and with most men it requires considerable experience, and long continued, intelligent effort.

NOTES ON THE GEOLOGY OF ROSSLAND ORE DEPOSITS.

E. Andrewes, Grad. S. P. S.

It may be as well in beginning a discourse on the subject of the geology of the Rossland ore deposits, to make mention of the most reliable matter for reference on the subject, which will be freely quoted from in the course of this paper.

The published literature on the subject is indeed not very voluminous. We have first of all Mr. R. G. McConnell's report, contained in the "Summary Report of the Operations of the Geological Survey of Canada for 1896." The report of Mr. W. A. Carlyle as Provincial Mineralogist, for the same year, contains information concerning the mines, and gives the history of Rossland as a mining camp.

In the "Journal of the Canadian Mining Institute for 1899," we have a paper by R. W. Brock, entitled "West Kootenay Ore Bodies," which is especially interesting in that it connects the Rossland ore bodies with those of the other parts of West Kootenay.

In the recent law suit between the Centre Star and Iron Mask Companies, the opinions of Mr. Clarence King, and Mr. Lindgren of the U. S. Geol. Survey, who appeared as expert witnesses for the Centre Star, were elicited concerning the general geology of the district and the nature of the ore-bodies.

Several eminent geologists and mining engineers made special studies of the Rossland ore deposits, and their mode of occurrence, in connection with this important law suit, but only the two named gave evidence at any length, as the case was adjourned, even before all the witnesses on the Centre Star side had been heard. Their evidence was published verbatim in the columns of the Rossland Miner, and affords much interesting information. Mr. W. F. Ferrier of the War Eagle Co., and the late lithologist of the Canadian Geological

Survey, read a paper in Rossland before the Canadian Mining Institute, while on their excursion there last summer, which,it is understood, dealt with the rocks of the district, and the occurrence of the ore deposit, but which, much to the present writer's regret, has not yet been published.

We learn from Mr. McConnell's report that the rocks in the immediate vicinity of the town of Rossland, and for some little distance round, belong to the older of a series of igneous rocks, which are spread over a wide area to the east and west of the Columbia River, and run some fifty or more miles north from the international boundary line, which of course is the southern limit of the region covered by his report.

These older rocks are the more basic of the series, and consist mostly of porphyrites, diabases, gabbros, tuffs, and agglomerates. The younger series consists of granite of various texture, colour and constitution.

"This eruptive series of rocks encloses bands and patches of dark fissile slates, which appear in most cases to be remnants of the formation amid which the igneous rocks were erupted, as none of the bands, even where 1,000 feet thick, can be traced for any distance along the strike. Slates holding small limestone bands occur on Trail Creek and other places."

These remnants are all that is still apparent of the original sedimentary rocks of the district.

The age of the igneous rocks is still uncertain, but Mr. McConnell says of the older granites that they are certainly post-carboniferous, and were probably erupted toward the close of the Triassic period. Mr. King, in his evidence, speaks of the Rossland rocks as being of Cretaceous age or thereabouts. Their age, however, is a matter of no great importance

Physiographically the region forms part of the southern continuation of the Selkirk Range, and is everywhere mountainous and rugged. It is dissected by several deep river valleys, including those of the Columbia and Kootenay.

The present configuration of the country is due chiefly to erosive forces, the numerous mountain streams having cut deep channels for themselves. In some cases great thicknesses of rock have been

removed from the surface, and that this has taken place to a marked degree at Rossland is evidenced by the rounded form of the mountains there, and the holocrystalline and generally plutonic nature of the rocks which come to surface there. The deep gravel deposits round the bases of the hill afford further evidence of the same thing.

If we now turn to the accompanying geological map of the Trail Creek Mining District, we see that the town of Rossland is situated in an area of rock, roughly oval in outline. This consists of a mass of igneous crystalline rock, everywhere of a basic character, but which varies considerably in texture and composition in different parts of its mass. In general it is an augitic rock of the nature of a gabbro or augite porphyrite. In parts we find a comparatively coarse grained rock with porphyritic crystals of augite. In other places it is fine grained and loses its porphyritic character. It contains both orthoclase and plagioclase feldspar, and hence is not a true gabbro. The orthoclase is often present in considerable amounts, and the rock of this character has been classified by Mr. Ferrier as monzonite, which is the name given to designate a rock bearing augite and a large amount of orthoclase feldspar. Some slides, examined by the author, taken from typical specimens of the country rock about 50 feet south of the Centre Star vein, contained numerous small grains of augite and brown mica embedded in a mass of small feldspar crystals many of which were untwinned. The augite is to a large extent uralitized to hornblende, a band of uralitic hornblende surrounding a core of augite being the ordinary form. The rock also contained numerous small grains of pyrite, which is also apparent to the naked eye throughout the whole rock mass of the area spoken of.

At the west end of the area is a considerable body of rock which contains hornblende, as a primary constituent.

These rocks in general are very fresh in appearance, exceedingly hard and tough, and may be characterized as typical greenstones.

This central mass of crystalline rock has been pronounced, and probably correctly, to be the core of an ancient volcano, which once towered far above the present surface level, and poured forth the vast quantities of lava, ashes, and rock fragments, which now form the series of volcanic rocks, which roughly speaking form a ring round their plutonic core. The variations in the latter may represent different periods of outflow. It is however a feature common to

many such igneous masses to show variations in their constituent minerals in different localities, and the Rossland rocks do but furnish another example of what has been frequently observed elsewhere. One class of rock shades imperceptibly into the next, and there is no sharp line of contact. They are all sufficiently alike in composition to cause them to be referable to the same magma.

The rocks which surround this central core are essentially volcanic rocks. They consist of lavas, porphyrites, breccias, volcanic muds and ash rocks.

"In passing outward from the gabbro area," McConnell's report runs, "a section, taken at almost any point, shows a bordering zone of brecciated porphyrites and diabases of varying width, but seldom exceeding a mile, beyond which comes an alternating series of porphyrites and slates, and still further away agglomerates, associated in places with fossiliferous limestones. Slates and tuffs occur with the porphyrites on Red Mountain, on Kootenay Columbia Mountain, and south of the gabbro area on Lake and Bald Mountains, and the ridge running south from them. Agglomerates make up the main mass of the rocks of Sophia Mountain, and occur with slates, tuffs, and porphyrites on Granite, Spokane, Grouse, and Look Out Mountains, and on the ridge immediately east of Sheep Creek."

These rocks are represented by the gray area on the map, and we see that they are spread over a large tract of country, and include many varieties, and also enclose remnants of the sedimentary rocks, which were the rocks of the district prior to the volcanic outbursts. The later granites occur as intrusive masses in them.

The central area of crystalline igneous rock, forming the volcanic core, as described above, is very important from an economic standpoint, as within it and around its edges are contained the large ore bodies, which have made Rossland famous. The most important of these, as we all know, are those which outcrop on the southern spur of Red Mountain, and within which are the workings of the Le Roi, War Eagle, Centre Star and other mines. We will consider these the typical ore bodies of the camp, as they are by far the most important. They are developed along lines of fissuring running approximately east and west, their strike varying from a few degrees south of west to a few degrees north of west. The largest outcrop is that of the main vein of the Le Roi and Centre Star, which strikes a few degrees

south of west, the War Eagle vein strikes a little to the north of west. They all have a northerly dip.

It seems to be the concurrent opinion of the geologists who have examined these large ore bodies, that they lie in what are termed shear zones, that is, zones of fissuring, up which the mineral bearing solutions have risen, replacing the country rock with their minerals borne in solution. Hence we also hear them spoken of as replacement deposits in a zone of fissuring. We find that such a zone is divided into approximately parallel sheets by lines of fissuring, the enclosed rock being impregnated with sulphides, or completely replaced by them with the formation of solid bodies of sulphide ore. It is probable that only in rare cases was their an open fissure formed, and the movement of the foot on the hanging wall has probably not been great, though abundant slickensides testify to there having been a certain amount of relative movement between certain portions of the rock. Mr. King says that such shear zones are formed under great compressive forces, which keep the fissures constantly closed.

This theory of formation is nothing but the most plausible interpretation of the facts we observe in connection with the Rossland ore deposits. We do not find one continuous vein of ore descending to a great depth, but a series of ore bodies, varying in dip and size, sometimes running parallel to one another, one being in the foot or hanging wall of the other. The intermediate rock is more or less mineralized, and one large ore body is usually connected to the next by small stringers or films of sulphides, which represent the series of fissures up which the mineral bearing solutions have passed. It would seem that the work of the solutions depended upon the condition in which they found the country rock, where it was crushed and easily acted upon they totally replaced it and formed large ore bodies, where it was hard and compact they merely left thin seams of sulphide a fraction of an inch wide along the fissures they traversed, and barely permeated the rock.

Fig. 1 is an imaginary sketch, but will serve to give an idea of what such an occurrence is like in cross-section.

Fig. 2 is a sketch from memory of an occurrence on the 625 ft. level of the War Eagle. The ore streak on the right is about 18 inches wide and is contained between two well defined walls. The foot wall streak is a single fissure on either side of which the rock is

thickly impregnated with sulphides. The intermediate space consists of altered rock more or less thickly flecked with sulphides, the central portion containing less than that close to the fissure.

It will be noticed that in neither figure are sulphides indicated in the rock of the hanging wall, and their absence is usually the case. In the 625 level however the hanging wall is, the writer believes, a dyke, of later origin than the vein.

The rock enclosed between and on either side of the fissures, which forms the principal gangue, is in all cases referable to the surrounding country rock, and is in many cases practically identical with it. As we might well expect in such a zone, it has been in places ground up, and other minerals such as quartz, calcite, and mica have been deposited in it, or its original constituents altered to these. Most of the rock connected with the veins contains a con-

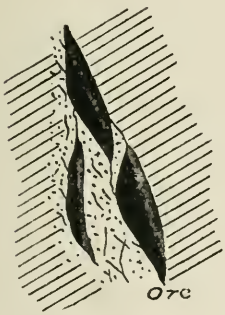


Fig. 1

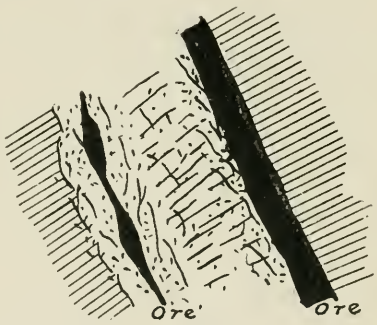


Fig. 2.

siderable amount of quartz, and we get little veins of quartz and calcite, usually mixed with sulphides. A striking feature in some places is the marked similarity in structure and general texture between the pyrrhotite ore and the rock. This is so pronounced that a freshly broken face of ore is often barely distinguishable at first glance from a face of rock, and it requires a close inspection by the light of a candle to detect the difference. The writer has known men to have taken a sample of a face after blasting, thinking that it was rock matter that they were getting, which on examination in daylight has been found to consist of almost pure pyrrhotite. In this case the

ore would appear to be what we might call a sulphide fossil of the rock it has replaced.

Mr. Lindgren said in his evidence: "The process by which the country rock is changed is called replacement. It is evidently caused by the introduction of solutions bearing different minerals, gold, copper, iron, and a great many other salts. This solution evidently acted on the country rock, introducing some minerals and forming others from the constituents which were already there; in fact more or less changing the whole aspect and composition of the rock. In favorable places the change to pyrrhotite and chalcopyrite went on more intensely. The minerals of the country rock were more or less completely replaced by these minerals. Their substance was dissolved out, and instead of the original substance the sulphides were deposited. A piece of petrified wood is an ideal example of replacement, not of the same character as the replacement in the rock, but it conveys the idea very nicely in that the substance of the wood is carried away, the *structure is largely retained*, but silica replaces the fibre of the wood. Impregnation is usually employed to signify the filling of minute pores in the rock. This impregnation took place in the case of the Centre Star vein; it probably always takes place, but it is subordinate to the main process of replacement, which I have already outlined." These remarks would apply equally as well to the other veins under discussion, as they do to the Centre Star vein, of which they were spoken.

One frequently finds dark spots, consisting of a chloritic mineral with crystalline outline, embedded in the phyrrhotite masses, which seem to represent the augite or hornblende of the original rock.

The sulphide minerals constituting the ore are pyrrhotite, by far the most abundant, chalcopyrite, and mispickel, while molybdenite zinc blende, and even galena have been found in small quantities. Molybdenite is quite an important constituent of the ore of the Giant mine. The ore minerals have not as a rule assumed a crystalline form, the fracture of the ore is very uneven without any sign of cleavage. Crystals of mispickel are not uncommon, and some very perfect ones are found in the Deer Park mine. There is only a small amount of pyrite in the large Red Mountain deposits, it occurs partly as a secondary constituent. Some of the other veins of the district contain the above-mentioned minerals in different proportions.

The deposition of the sulphide ores from hot solutions is borne out by the occurrences of zeolites along the vein fissures. They occur lining and often filling open spaces, which occur at intervals in the fissured zone. Several varieties are found, laumontite being the most common. They often assume a very beautiful crystalline form, which is enhanced by their limpid pearly lustre, when first taken from the mine, before they have lost their moisture. Zeolites are generally considered to have been deposited from heated waters. We thus conclude that the Rossland veins are of deep seated origin, and as the rocks in which they occur have been formed in place from the molten condition, being erupted from below, the condition under which the ore bodies occur should hold to practically unlimited depths.

Subsequently to the formation of the ore bodies a further breaking up of the rock mass on lines running approximately north and south has taken place. This is marked by the occurrence of numerous dykes, which cut through the veins in a great many places, and have as a rule an easterly dip of 70°—80°. The rock filling them is a typical dyke rock of the nature of a lamprophyre. It is dark in colour and easily distinguished from the country rock. The walls of the dykes are generally well defined smooth planes. In coming upon them in mining, the change from ore to dyke rock is often quite abrupt, the plane of division being a perfectly well marked smooth plane. In other places warning of the approach of a dyke is given by bits of dyke rock appearing in the ore, which gradually disappears entirely. The dykes do not often exceed 10 feet in thickness, and are sometimes no more than a foot thick. The veins appear to be very little displaced by them, if at all.

Faulting has taken place on planes parallel to the dyke, in at least one notable case, in the War Eagle vein, which may have been caused by the same set of forces which opened up the fissures for the dyke.

In conclusion let it be said that the writer does not pretend to have fully dealt with the geological problems of the Rossland district in this paper. He has, however, endeavored to make plain the relation of the grander rock formation of the district, to set down certain facts concerning the ore bodies and rocks which he himself had the

opportunity of observing in eighteen months close acquaintance with one of the principal mines, and to bring to the notice of the meeting the conclusions which have been put upon these facts by those eminent geologists who have examined and given evidence concerning them. If his hearers have been interested in listening to the course of this paper he is gratified, and if they know more of rocks and ore deposits of Rossland than they did when he began, his efforts are more than repaid.

MINE TIMBERING.

E. V. Neelands, '00.

Like most kindred sciences, mine timbering has reached its present advanced state of development, as a result of exigencies in particular cases. The methods in vogue now, in mines where the greatest success in mining engineering has been attained, have been arrived at as a result of experience, the systems which have proved themselves the best under given conditions having been retained and the others rejected. Timbering underground cannot be reduced to the same mathematical science as similar work could be in surface operations, owing to the varied conditions and the complicated nature of the stresses to which it is subjected. In general, sound commonsense and the application of a few principles are sufficient without making any attempt to calculate the size of the different members of whatever construction may be contemplated.

The following general rules may be said to apply universally:

1. The greatest strength of the construction should be in the line of the probable thrust.

2. An absolute rigidity in the construction should be aimed at, by wedging or other means.

3. A firm, permanent foundation should always be secured.

4. All joints should be flat.

5. The timbering should never, even temporarily, be allowed to fall behind the mining operations.

The advantages of the principles embodied in the foregoing rules are so self evident that a further examination of them is unnecessary.

Mine timbering may be divided into three departments; according as the work is done in shafts, stopes or tunnels (including drifts and adits), each having its own peculiar features.

In the first, the construction is dependant upon the shape of the shaft, the nature of the ground and its inclination to the vertical. In America the rectangular shaft is almost universal, as it is economical and is easy to timber. In Europe where stone and brick are more largely used for lining, the circular form is common.

The shaft should be timbered as the sinking goes on, even if the walls are hard and self-sustaining. "Hitches" are cut in the rock in which "reachers" are placed which support the sets, every 20 or 30 feet apart, each successive pair being at right angles to the preceding ones. If the ground is bad the "reachers" are suspended on iron dogs, 1 inch in diameter, from the set above, and afterwards firmly wedged. In firm ground a lining of 3" plank is sufficient. Shoulders are cut and the planks, two wall pieces and two end pieces, placed in position without nailing, but held firmly in place by packing the waste rock between the wall and the lining. If the ground is bad a casing of larger timber up to 10" is used, their ends being shouldered and laid "skin to skin."

The new shaft of the Centre Star Mine in Rossland may be cited as an example of good modern shaft work on a small scale. The shaft has three compartments, and is in fairly firm ground. There are five different members used in the construction, not including the guides (Figs. 1, 2, 3, 4, 5, 6, 7, 8). Figs. 1 and 2 show the elevation and plan of the timbering, Fig. 3 shows the end of intermediate cross timbers, showing cut at *H*. Fig. 4 the inside face of side collar timber *A* showing cut at *F*. Fig. 5 the inside face of side timber. *C* showing cut at *F*. Fig. 6 gives end view of the post *D* (both ends the same). Fig. 7 the end of intermediate post at *D*, showing cut at *D*, (the ends being similar), and Fig. 8 shows the end of side timbers showing cut at *C* (both ends being the same). Pine is used throughout the construction, all timber being of course framed on the surface.

Should a cave-in occur in the shaft it is a frequent practice to put in crib work to fill the place of the removed rock. An instance of this may be mentioned. An extensive cave-in, causd by stoping alongside the shaft, occurred at the 200 foot level station in the Le Roi Mine, and the shaft is now strengthened by an elaborate system of crib work, for upwards of 100 feet.

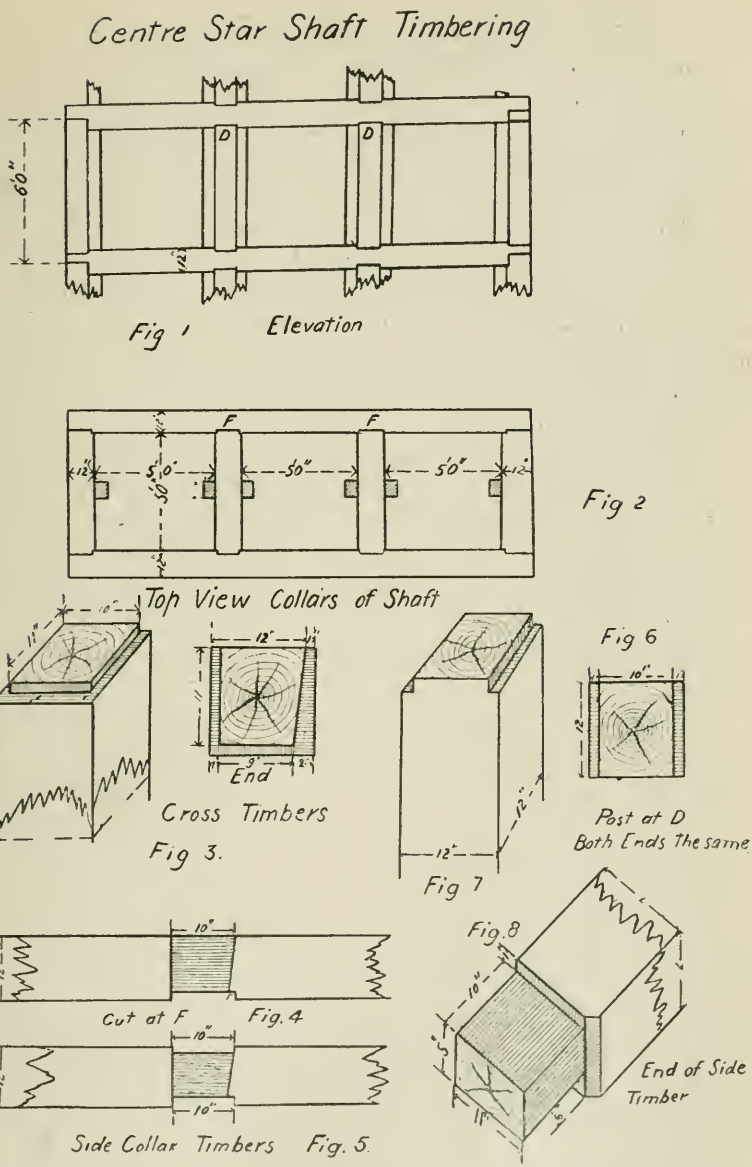

Centre Star Shaft Timbering
60"
D
D
12"
Fig 1 Elevation
F
F
12"
5'0"
5'0"
5'0"
5'0"
12"
Fig 2
Top View Collars of Shaft
10"
12"
9"
End
Cross Timbers
Fig 3.
12"
12"
Fig 7
Fig 6
10"
12"
Post at D
Both Ends The same
10"
12"
Cut at F
Fig. 4
10"
12"
10"
Side Collar Timbers Fig. 5.
Fig. 8
10"
5"
11"
6"
End of Side
Timber

PLATE I.

Timbering in stopes varies according to the size of the chamber, the dip, and the nature of the ore and walls. The cost of the timber is also a not inconsiderable factor. Little timbering is required in narrow, steep veins, with good walls. Occasional stulls are used resting in hitches cut in the walls. They are placed in rows about 6 feet apart, lagging being laid on them to serve as a platform to work from and to receive rock from the blast. They should be placed at a slightly smaller angle to the vertical than the perpendiculars to the walls, and should be firmly wedged. If the wall is soft, timber should be placed to act as a plate behind the ends of the stulls. Many methods have been devised for strengthening the single stull, the most common forms being stulls extending from hitches cut in the walls, as props in the form of an inverted V, and for soft ground the props are perpendiculars set against the walls.

Ihlseng gives the following formula for calculating the diameter of a single round stull $d^3 = 0.05\ hw^2m$, where h is the height of the wall along the vein, in the distance between the stulls, w the width of the vein, and d the diameter of the stull, the strength varying directly as the cube of the diameter. It is better to increase the number of props than the diameter.

For timbering large stopes, several elaborate systems have been devised

The square sett system is at present the favorite. It was first introduced in the Comstock Lode and when its advantages were fully appreciated it speedily became the most approved method. Fig 9.

The following is the method of putting up the setts employed in the Le Roi Mine in Rossland. The muck is scraped away till firm rock is reached, on this a 3″ plank is laid, to serve as a mud sill, perpendicular to the walls, on this, posts are set up 4′ 6″ apart. The posts at the top fit into a cap which extends across them parralled to the mud sill from the hanging wall to the foot wall. Hitches should be cut and the whole firmly wedged. The mud sills are about 4′ apart, the setts are supported from the sides by collar braces from cap to cap. The shoulder of the cap should fit into the end of the post in order to prevent any lateral motion on the part of the latter. Foot braces are nailed in between the posts, they consist of pieces of plank of about 3″ x 4″ size, of the proper length, driven in and nailed. These should be the only nails used in the construction.

STOPE TIMBERING — LE ROI

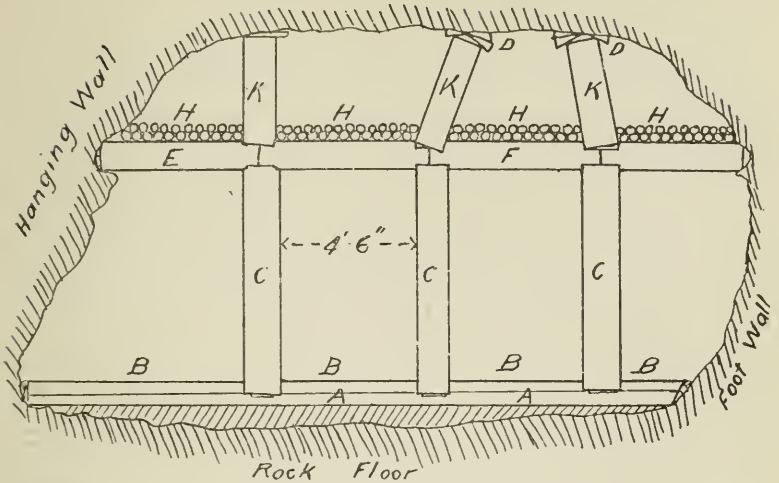
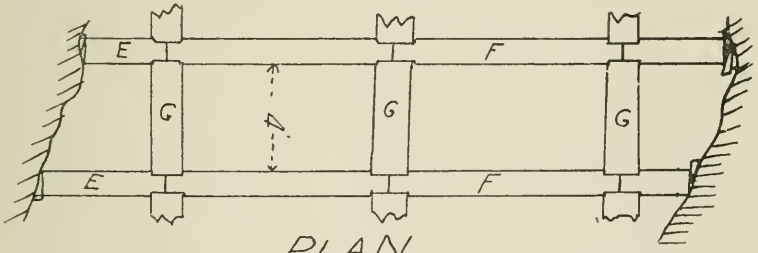


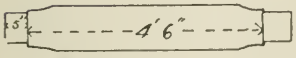
Fig. 6 CROSS-SECTION



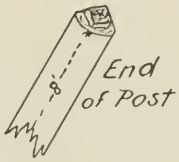
PLAN

Lagging and Spraggs removed

A,A – mud sill
B,B – foot braces
C,C – posts
D,D. – wedges
E,E – butt cap
F,F – cap
H,H – lagging
K,K – spraggs



CAP
Fig. 7



On these caps another series of posts can be set up and the series continued till the roof is reached.

From the caps of the top sett a number of spraggs extend to the roof to support it, and to keep the whole system of setts rigid. These spraggs at the Le Roi are usually cut from the poles used for lagging and are driven in tight and wedged.

Across the caps of the upper setts lagging is laid to protect the men working below. In Rossland poles 4″ to 8″ in diameter, and about 16′ long are used. They should be double laid wherever they are expected to receive the muck from the blasting. These poles can be shifted from floor to floor as the work goes on, and thus an important saving is effected.

For handling the muck, perpendicular chutes are used, of such a size as to occupy the space between four posts. Braces, 3″ plank, are set in grooves cut in the inside of the posts, and then 3″ planks are spiked from cap to cap and collar brace to collar brace, to form the sides of the chute. If the drop exceeds about two floors it is customary to shift over a sett in order to break the fall and minimize the wear and tear at the bottom where the muck is delivered into bins which are periodically relieved by cars.

Figs. (7*a*, 8*a*) illustrate the above method. Fig. (7*a*) shows the cap, plan and elevation being the same. Fig. (8*a*) shows the ends of the post and collar brace. Fig. (6*a*) shows the plan and end elevation of stope timbered by square setts.

If great strength is required crib-work is sometimes used. A good foundation should be obtained and two or three logs are laid parallel and upon them in notches cut near the ends, cross sills are laid and then more logs parallel to the first, the spaces are filled up with smaller timbers wedged tight by, or with waste. Crib-work is sometimes built up on the top of the upper row of square setts to reinforce the spraggs which are temporarily supporting the roof.

In swelling ground such as felsite or trachyte, it is customary to have some weak points in the frame which can readily be replaced and thus save the whole construction. It is of the utmost importance that any indication of a movement should be at once attended to, as with each member displaced, an additional strain is forced upon the others, and in a comparatively short time the chamber may be lost beyond recovery.

Methods of timbering in tunnels depend mainly upon the nature of the ground in which operations are being carried on. In narrow drifts in good ground it is not considered necessary to reinforce the natural supporting walls by artificial means, but in tunnels of sufficient size for extensive operations some timbering should be used even in the firmest ground. To support a scaly roof a series of setts is sometimes used. A row of posts are set up on sills about four feet apart on each side of the tunnel and a cap laid on each pair, the ends being carefully framed. Ties extend across between the setts to hold them firmly in position. It is customary to let the posts incline slightly towards the centre of the tunnel to enlist the principle of the arch. If the tunnel is wide enough for two tracks a row of posts is put in to support the cap in the centre. Along the caps lagging is laid in double or single rows according to the nature of the ground. If one wall is good one end of the cap is sometimes allowed to rest in a hitch, while a post supports the other as above. Care should be taken in timbering tunnels to allow room for a passage-way for the men. Upwards of 12 per cent. of fatalities in mines being due to crushing by cars in haulage-ways.

Iron and masonry are beginning to play an important part in underground work. In Europe, owing to the cost of timber, they are put to extensive service. Old iron rails and posts of a circular form are largely used, especially when the conditions are favorable to an early decay of ligneous matter. Masonry is frequently used for lining shafts, especially in the Old World, but it is necessary that the ground be strong enough to stand without support for a couple of weeks, as to obtain a sure foundation, a considerable depth must be reached. In some cases a V-shaped chamber is built into the rock to obtain the necessary stability. In tunnels, if one wall is solid, a hitch is cut to act as support and an arch built around to the ground on the opposite side; if both walls are bad, a complete arch is built, or sometimes an ellipitical form is used.

Iron and masonry possess a great advantage over wood in their resistance to decay. The life of timber depends on the condition of the atmosphere and the care taken in dressing. The effect of the heavy hot air of a mine is a decomposition which can only be stayed by better ventilation or the use of antiseptic preparations. A constantly changing temperature, or a variation in the amount of mois-

ture, is very destructive. A cotton-fungus mould is a sure sign of a bad atmosphere. As this fungus spreads rapidly it should be attended to at once. In stopes in the Le Roi, not over four years old, timbers twelve inches in diameter have fallen apart through sheer rottenness due to this cause, the mould being in many cases a foot long.

The destruction of the timber, which is due to the damp air, the attacks of insects, and the fermenting of the albuminoids of the sap may be materially delayed by chemical treatment. Creosote is largely used for this purpose. It is forced into the timber by placing the latter in an iron chamber from which the air has been extracted, and then admitting the creosote under a pressure of about 100 pounds per square inch. In salt mines, steeping in brine has been found to give increased endurance to the timber. The sulphates and chlorides of zinc also prove excellent antiseptics.

Care should be taken in the selection of the timber, but the choice is often influenced by circumstances. Oak is the best for general purposes, but that which is most convenient is generally accepted. Spruce and pine are also good, but such woods as cottonwood should be rejected. Well seasoned timber is desirable under all conditions, as it combines the essential features of good material, strength, lightness, and durability.

A TRIP TO THE YUKON.

L. B. Stewart, D.L.S., D.T.S.

Notwithstanding all that has been said and written about the Yukon region, many false impressions of that country still prevail. Foremost among these is the impression that it is a scene of barrenness and desolation, devoid of vegetation and possessing such a rigorous climate that none but the hardiest should venture there. The responsibility for this opinion is perhaps to be divided between the wrttten reports of early explorers and the accounts of their adventures related by disappointed gold-hunters on their return. The latter may perhaps be excused if they retained no pleasant recollections of the country when, after having undergone all the hardships and privations entailed in a journey to the gold-fields a few years ago, their labors were not crowned with success.

The country however is neither barren nor desolate. While by no means thickly wooded, it has sufficient timber both for manufacturing into lumber and for fuel to last the present population for many years, though the steamers plying on the river will be obliged to draw their supplies of fuel from points farther and farther from its banks from year to year. Coal, or a good quality of lignite, has been found, and is being worked in various localities, and will prove a valuable addition to the resources of the country. Gardening, and farming on a small scale, have been tried with success in sheltered spots, and I have no doubt that many who have gone there with other objects in view will be induced to adopt this as their means of livelihood, and may derive more profit therefrom than the average miner in his search for gold, as there is a ready market for all sorts of garden produce. I was told that one man cleared $12,000 from his garden in one season. Once the summer begins, growth is very rapid owing to the great length of the days, as by a kind provision of nature when the sun is north of the equator the duration of sunshine is greater the farther north the place may be. The climate

also has nothing to be dreaded. I can speak in the highest terms of the summer climate; it is dry, cool, bright, and bracing, and can only be found fault with, I think, by those that object to being obliged to feel energetic. The incessant daylight, lasting for about three months, is a distinct advantage in a country where the principal occupations necessitate a life in the open air, and where travelling must nearly all be done on foot. The prospector, in setting out on a trip, is enabled to dispense with blankets, thus materially lightening his pack, by sleeping during the day when it is warm, and working and travelling during the night, or that part of the twenty-four hours when it should be night. As regards the winter, I am told by those who have lived also in Manitoba, that the winter in that province is much more trying than that on the Yukon, as there is more wind. The darkness of the winter months is certainly a drawback, but this is mitigated by the frequent northern lights and by the brightness and long continuance of the moonlight.

The climate of the strip of country between the coast range of mountains and the sea, belonging to our neighbours across the line, is entirely different from that of the interior, being warmer but damp and foggy.

On May 27th last I set out for Dawson in search of as much wealth as could be gained during the summer months. Arriving in Vancouver on June 3rd, I at once set to work to make inquiries regarding routes and rates and to purchase a small camping outfit. I finally bought a through ticket to Dawson from the Canadian Development Company for $135. I found afterwards that nothing was gained by getting a through ticket, and by doing so one lost any advantage that was to be gained by cutting of rates on the Yukon. My steamer was to leave on the following Monday, and the time at my disposal was fully occupied in completing my outfit and in getting my "outward entry" papers made out by a broker, a very essential proceeding as appeared later.

About 9.30 p.m. our steamer, *The Cutch*, pulled out from Vancouver. The following morning found us nearing Seymour narrows, where the tide runs so strongly that small steamers cannot make headway against it, so we were obliged to heave-to for an hour or so to await the turn of the tide.

The trip to Alaska by the inside channel has been well-known to tourists for many years, so that a detailed description of it need not be given here. The whole route lies through narrow channels among islands, sometimes so narrow and of such length that it is hard to believe that one is not on a river; at times the steamer seems to be running into a cul-de-sac, when an outlet appears in an unexpected quarter. Everywhere the land is mountainous and rugged in the extreme. The only parts of the route where those most susceptible to mal-de-mer need feel any uneasiness are in Queen Charlotte Sound and Dixon Entrance; at these points the full sweep of the Pacific must be encountered for a few miles, which generally reduces the crowded appearance of the decks. On our arrival at Skeena river the tide was out, so we were obliged to wait for higher water in order to land our freight, which gave us a chance to see the process of canning salmon, from the time the fish are taken from the water until they are packed in the cans. The morning's catch was being landed on our arrival, and before we left, early in the afternoon, they were all canned, so there is not much time lost in the operation.

On Saturday, June 10th, we reached Skaguay in a shower of rain, and with the surrounding mountains hidden by cloud banks, a very common state of affairs there. On landing we had the usual encounter with customs officers, and then proceeded to enquire as to the best route to the Yukon. My ticket provided me with a passage over the White Pass by rail as far as the railway extended, but we heard the comforting news that endless tons of freight were piled up at the end of the track, from which point it was being slowly forwarded to Bennett by pack horses, and that any freight shipped now would have to await its turn. The company offered to express anything to Bennett at the rate of seven cents per pound, and to deliver it there without much delay; but we were assured by others who professed to know all about the matter, that the trail was almost impassable, and that nothing could be delivered in less than ten days. The agents of the Chilkoot Pass route made similar promises, but that route also had its detractors, and while trying to find out the truth, the choice of a route was decided for me by the customs broker whom I employed, through a misunderstanding, bonding my things through by the Chilkoot route. To save time, and finding

that others had chosen that route, I decided to let matters remain as they were. A rule always to be observed in that part of the world is never to go ahead of your outfit, always keep it ahead of you, so that evening I saw my camp outfit leave for Dyea on a scow, and the following morning took my baggage across in the ferry and saw all loaded on a wagon and started up the pass. I then returned to Skaguay and collecting the rest of my belongings, I recrossed to Dyea accompanied by Mr. R., whom I had met on *The Cutch*. We decided to remain there a day to give our baggage a chance to reach Bennett ahead of us, and then follow after it, keeping a sharp look-out in case it should have been side-tracked anywhere. We landed from the ferry on the dock, which did not extend inland as far as high water, and the tide being in we were cut off from the shore. A man with a skiff offered to row us ashore for 50 cents, but we were getting tired of paying 50 cents or $1 at every turn, so we decided to await the ebb of the tide, and in a short time the water was shallow enough to allow us to wade ashore.

The construction of the railway over the White Pass has built up Skaguay at the expense of Dyea, which at this time was almost deserted, the employees of the Chilkoot Aerial Tramway Company being about the only inhabitants. Freight was transported by wagons from this point about eight miles to the beginning of the canon at Canon City, so-called, thence by cable tramway to the summit of the pass, nine miles farther, from which point it is drawn on sleighs as far as the snow extended, thence by pack horses to Lake Lindeman, thence across Lindeman by scows, and finally by wagons to Bennett. All this was done at the rate of five cents per pound. At this time the Chilkoot route was preferable to the other as far as the transport of freight was concerned, but the completion of the railway has of course changed that. In the days of pack horses the Chilkoot Pass was the summer route, being the shortest from water to water, and the White Pass the winter route, being about 900 feet lower, and having at the summit a chain of small lakes which made a good winter trail.

The next day we set out about noon by stage and arrived at Canon City about three or four o'clock. After lunch we started for Sheep Camp, our party now increased to five, and arrived there after a couple of hours scramble over an extremely rugged but picturesque

trail. Sheep Camp is a small settlement just below timber line, and was an important point in the days of packers. Here we spent the night, resolving to proceed very early in the morning before the sun had time to melt the snow on the pass, as then walking was much more difficult. By three the next morning we were again on the way without having any breakfast, as no one in the hotel was stirring except ourselves, and we had not gone far before we began to feel the omission very keenly, and often was the question asked, "who proposed setting out before breakfast"; but nobody knew. The trail became more and more rugged as we advanced, winding among or climbing over large masses of rock fallen from the mountain sides. Then snow was reached, and after clambering up a steep slope the walking became easier until we came to the place called the "Scales." Here in front rose what looked like a huge bank of snow, very steep, and with its summit lost in a bank of cloud. The most direct path from here was so steep that steps had to be cut in the snow to make climbing possible, a rope serving as a hand-rail, and I have been told by those who crossed the pass the previous summer that at every few yards the climber would meet somebody who would tax him a quarter for keeping the steps in order. Last summer a more roundabout path was generally used, which gave a slightly easier grade, but if the one we took was the easier I am glad we did not take the other. I could not help a feeling of admiration for the physique of the man who could carry a pack weighing 100 or 150 pounds up that slope. On arriving at the summit we were enveloped in fog, which prevented us enjoying the magnificent view to be had from there, especially towards the south, but even if the sky had been clear it is not likely that men who had climbed nearly 3,000 feet in a walk of about five miles before breakfast would be in a fit state to enjoy scenery with breakfast only a quarter of a mile ahead. It took only a few minutes to slide down the other side of the slope to Crater Lake, in the middle of which, built on the ice, was a small "restaurant," where we were soon enjoying a well-earned meal.

R. and I then pushed on at once for Bennett, the others remaining behind for the present, and a few miles brought us to the end of the sleighing. Here large tents were pitched to shelter the freight until it could be carried farther by the pack animals. Soon we

overtook a train of forty or fifty pack horses and mules laden with every imaginable article from the ordinary bale to large packing cases, furniture, doors and window sashes, and even some barber's chairs; the ingenuity of the packers must have been well tested. A little later Lake Lindeman appeared in sight, and soon the little settlement on its shore lay almost at our feet at the foot of a steep hill. The trail curved away to the left to descend the hill by an easy grade, but seeing a hotel not far away and being again hungry, we were not content to keep the trail, but struck down the hill and across the flat at its foot to reach the hotel as soon as possible. We had not gone far when a peremptory whistle made us look round, when we saw a mounted policeman beckoning to us from in front of a neatly built log building. The Union Jack floated from a flag-staff in front of the building, and the word "customs" escaped from both of us simultaneously. The collector evidently thought that we were trying to evade H. M. customs, when our sole object was the innocent one of appeasing our mountain appetites as soon as possible. Having satisfied the policeman that we were not smugglers, and enjoying the comfortable reflection that we were again in Canada, we proceeded on our way. In the afternoon we saw all our effects loaded on a scow to be taken across the lake, and then crossed over ourselves and reached Bennett about 6 p.m.

Bennett is an important point just now, being the terminus of the railway and the head of navigation of the branch of the Yukon that serves as the highway into the Klondike district. The old pioneers used to pack their outfits over one of the passes and then build boats here of lumber sawn by hand in the woods to take them down the river to their destination. Quite a business is still carried on in scow-building; one can be purchased for $700, built of lumber sawn on the spot, and where one has a large outfit they probably afford the cheapest means of getting down the river, as they can be sold in Dawson or the lumber used for house building.

After a delay of a couple of days waiting for a boat I got away from Bennett on the *Australian*, Mr. R. having taken another steamer for Atlin the day before. After a slight delay at Cariboo crossing from shallow water we arrived at Tagish, i.e., at the police post at the foot of the lake of that name. Here a certain amount of

uneasiness must have been felt by some of the passengers in consequence of a notice posted everywhere stating that anyone going into the country for the first time must satisfy the police officers that he possesses at least six month's provisions and $500 in cash. This action on the part of the government was necessitated by the large number of indigents they had been obliged to support during the winter. As I should have had some difficulty in satisfying the police that I could comply with the letter of the notice, I took care not to look for any of them and they did not look for me. The next morning early we reached Miles Canon, where a break occurs in the navigation of the river, a wooden tramway five miles in length connecting the landing above the canon with that below White Horse rapids for portaging baggage and freight, the passengers generally going on foot. Here I made the mistake of going ahead and trusting to another to look after my things, which cost me a delay of eight days. A steamer was waiting at White Horse, but as my freight had not arrived I was obliged to let it go out without me. My enforced stay there I spent as best I could, exploring the surrounding country, taking snap shots at scows running the rapids, etc. Pilots on this part of the river make quite a profit from steering scows through the canon and rapids; they charge a pretty high figure, but I was told insure the cargo against loss by depositing its value with the police, which they forfeit in case of accident. Accidents are rare however where pilots are engaged, as once the peculiarities of the rapids are understood they give no trouble even to a good canoe. The canon is not nearly as serious an affair as the rapid, though neither should be run by any but experienced boatmen.

Curious stories are told of how two men would sometimes go into partnership in purchasing a scow and outfit to descend the river, but quarrelling before their destination was reached they would dissolve partnership and make an equal division of their property. To make a fair division the aid of a policeman was generally called in, and everything that could not be readily divided was cut in two. The scow would be sawn in two and the ends boarded up, the cooking stove would share a similar fate, and in short where there was only one of anything it would be cut in two, each taking half. On one of these occasions it was thought that everything had been divided when a frying pan was produced, and having no means of

dividing it the disgusted policeman hurled it as far as he could into the river, and both parties were satisfied.

After leaving White Horse I hoped to reach Dawson without further delay, but again met with disappointment. Either through a difficulty in steering the boat, or incapacity in the wheel-house, or both, our steamer soon developed a strong desire to become acquainted with every rock and sandbar in the river, and where there were no rocks or sandbars the shore answered just as well, and in it great V's were cut by our bow that would serve as harbours for small canoes, and then the shore would retaliate by breaking our rudders whenever the stern of the boat came in contact with it. The steamer Domville had sunk in Thirty-Mile river a few weeks before, filling about half the channel; the other half was not wide enough for our steamer, which struck the paddle wheel of the Domville and then her stern swung round in the current and lodged against the bank, thus completely filling the channel. This caused a delay of about ten hours. Later on we floated broadside on a bar at the head of an island when there was a deep channel on each side of it; hesitation as to which channel to take until it was too late to take either probably caused this mishap. Another delay of nine or ten hours ensued.

Everything must have an end however and we reached Dawson at last on June 30th. As an instance of the readiness with which nicknames are added to a man's name in that country, I may relate that on my return journey in coming up the river I heard some men discussing a certain "Sandbar Robinson" (the name of course fictitious), but at first it did not occur to me that they were speaking of the captain of the steamer on which I travelled down the river.

On approaching Dawson by water one is not likely to be favourably impressed with its appearance, though one's expectations of a place that has grown up so quickly and under such unfavourable conditions should not be very great. The principal part of the city is built upon an extensive flat, which when viewed from the river is completely dwarfed by the mountain or dome, as it is called, which rises abruptly in the rear to a height of 1,500 feet or so above the river. In a place whose population regard themselves as birds of passage, the buildings are not likely to be of a very substantial character, and this is the rule in Dawson, though some of the large trading companies have shewn their faith in the permanency of the min-

ing industries of the region by erecting extensive warehouses, well built of timber and corrugated iron, and storing them with provisions sufficient to last the community for years. I have no doubt that events will shew that their faith has not been misplaced.

One thing that is apt to strike the newcomer rather unpleasantly, and especially if his finances are at a low ebb, is the high price charged for everything. After collecting my things I engaged a carter to take them to a place where I intended to pitch my tent, and found that his charge was $4 per hour; this was explained by the fact that hay cost 20 cents a pound, and it had been as high as 30 cents. The prices of staple articles, however, are now quite reasonable; it no longer pays a man to take his own supplies into the country, unless perhaps he is taking a considerable quantity, and carrying it by scow down the river from Bennett. Good meals may now be had from $1 upwards in Dawson, though out on the creeks the price increases with the distance from the city, reaching as high a price as $2.50 on Sulphur Creek for a very ordinary meal such as one could prepare for himself in camp.

The day after my arrival in Dawson I became a partner in a firm of land surveyors, and was at once as busy as one could desire.

The bulk of the work done by surveyors being the laying out of mining claims, a brief description of the method of survey may prove of interest. According to the regulations in force prior to January 18th, 1898, under which nearly all the claims in the Klondike region were staked, creek and gulch claims were 500 feet in length, following the general direction of the creek or gulch at that point, and extended back in width from the creek to the base of the hill on either side, except where the distance from the creek to the base of the hill exceeded 1,000 feet, in which case the posts marking the side boundaries of the claim were planted at the distance of 1,000 feet from the creek.

A prospector in staking a claim generally blazes two trees on the bank of the creek at the estimated distance 500 feet apart, and writes on each a statement of the length claimed, the direction in which it extends from that point, whether up-stream or down-stream, and dates and signs it. As the education of the average prospector is usually limited, and he is in many cases a foreigner, many of the inscriptions on posts afford amusing reading. One post met with by

a surveyor contained the simple and direct statement, "I clem this clam," and a Norwegian signature that would have been quite unintelligible if the surveyor had not been assisted by the records in Dawson. The decipherment of these inscriptions is an important part of the surveyor's duties, the survey being based upon the location posts, and he must often bring to bear upon the matter the mind of a Sherlock Holmes, as there are many causes that tend to make the identification of a post after two or three years have elapsed, a matter of extreme difficulty. Fires may sweep over a piece of country completely effacing any writing made on the trees, or an unscrupulous individual, in whom the country abounds, may re-blaze a tree, substituting his own name for that already there. In the latter case the post may often be identified by finding the original writing on the chips lying about, but these are now usually collected carefully and burnt. In one instance that came to my notice the tree that served as a location post had been cut down close to the ground and a portion of it removed to mark the boundary of an adjoining claim, but fortunately we were able to identify it unmistakably.

Having found the location posts, the surveyor then runs a base line in the general direction of the valley and along the course of the creek, or produces the base of an adjoining claim already surveyed, and then runs the cross lines through the location posts and perpendicular to the base line, producing them to the base of the hill on either side of the valley. If the length of the claim, laid out as above described, would exceed 500 feet, its length is made exactly 500 feet, commencing at the location post nearest discovery claim, the overplus constituting a fraction, which is retained by the government. The surveyor must use his judgment in determining the base of the hill. In a good many cases the staker blazes two trees, one on each side of the track, at each end of the claim; in that case the end boundaries must pass through points midway between the location posts.

Under the existing regulations creek claims are laid out 250 feet in length, the length being measured in the same way as under the old regulations, but the side boundaries are "lines along bed or rim rock three feet higher than the rim or edge of the creek, or the lowest general level of the gulch within the claim so drawn or

marked as to be three feet above the rim or edge of the creek or the lowest general level of the gulch opposite to it at right angles to the general direction of the claim for its length, but such boundaries shall not in any case exceed 1,000 feet on each side of the centre of the creek or gulch." Unless bed rock is exposed, the positions of the side boundaries can only be determined as the claim is worked.

After finishing some work in Dawson I set out one morning about eight to join my partners near the "Forks" of Bonanza and Eldorado creeks, where they had been engaged for a few days in surveying some claims. I carried my instruments and was accompanied by a man who was anxious to have some work done. After what seemed like a continuous wading through mud half way to our knees, for the creek valleys are usually very swampy in the Klondike, we arrived about noon at a point a little below the Forks. Here a shingle nailed to a post beside the trail indicated that my partners were working on the adjoining hillside, so we turned aside into a road-house for lunch before looking for them, and found that they had spent the previous night there. While having lunch one of them appeared, and presently we set out together and spent the afternoon finishing some work in the neighbourhood. After having supper at a miner's cabin we separated, Mr. B. striking across the ridge to the eastward towards Hunker Creek, and Mr. F. and myself setting out for Sulphur Creek. The distance was about 20 miles, but we resolved to walk as far as possible before resting. We followed the trail up Bonanza Creek to near its source, and then took a trail that leads over the divide that separates the Klondike basin from that of Indian River. After walking till two in the morning, the last five miles involving a climb of a couple of thousand feet, we found ourselves beside a road-house at the summit of the divide that advertised "lunch at any hour of the day or night," and this proved too attractive, so we turned in there, and after enjoying a "lunch" we retired after giving instructions that we must not be disturbed until further orders. About noon the next day we again set out and arrived about the middle of the afternoon at our destination, and taking up our quarters at a convenient road-house we spent the next few days in laying out several claims. Having finished our

work about noon on a certain day, we set out after lunch for Dawson, reached the Forks at six for supper, and arrived at Dawson shortly before midnight, having walked about thirty-three miles.

The above will serve as a sample of a surveying trip on the Klondike creeks, and, needless to say, one takes with him on such a trip but little besides his instruments. After being away from Dawson for a week or more one becomes very hungry for news from the outside world; on one occasion I paid a newsboy 50 cents for a Toronto Evening News a month old, and at another time the same price for a copy of the Mail and Empire, also a month old.

A few words should be said with regard to the mines, and the prospects of mining in that region. In this respect the country has not, I think, been exaggerated. Though the number of extremely rich claims is limited, there are a great many that will pay well for working, and a great many others that will pay well when worked in larger areas and by cheaper methods than those now in use. The two principal methods employed in the Klondike are by summer sluicing and by sinking shafts and drifting. Mr. Treadgold in his report on the Klondike makes a careful estimate of the relative cost of the two methods, placing the former at $5 and the latter $10 per cubic yard, so that any gravel yielding less than these values can at present be worked only at a loss. An idea of the expense of working a claim may be gathered from the fact that from a certain claim on Dominion Creek $110,000 were taken in one season at a cost of $90,000 exclusive of royalty. This may, of course, be an extreme case. The chief source of expense is the frozen ground; frost is always encountered at the depth of a few inches, and extends to the greatest depth to which any shaft has been sunk.

After the present small claim owners have worked out or abandoned their claims, long stretches of several miles of the creek valleys will be leased by companies with capital, who by using hydraulic machinery will be able to extract the gold which remains after the cruder methods now in use have failed.

A few figures taken from Mr. Treadgold's report will shew the richness of some of the claims. He says: "On a fair claim on upper Bonanza a cut 120 ft. x 30 ft. yielded 980 oz. On Eldorado a cut 120 ft. x 30 ft. yielded 12,000 oz. On lower Bonanza a cut 30 ft. x 30 ft. yielded 95 oz. On another lower Bonanza claim a similar

30 ft. x 30 ft. cut yielded 580 oz. On upper Hunker a cut 120 ft. x 12 ft. gave 69 oz. On lower Hunker a cut 100 ft. x 50 ft. gave 1,800 oz.," etc. At $15 or $16 an oz. the values of these cuts may be computed. He also states that he has taken 40½ oz.—over $600—of gold from about 20 lbs. of gravel. An estimate is also given of the probable total amount of gold that will be taken from the proved creeks of the Klondike region, including also the northerly tributaries of Indian River, based upon a total length of 75 miles, a width of 150 ft., and a depth of 3 ft. This mass of gravel at ½ oz. per cubic yard will yield 3,300,000 oz.; and all who have been in the country will, I think, regard this estimate as a moderate one.

The country, besides being rich in precious metals, must also be an extremely interesting one to the geologist; the organic remains imbedded in the gravel deposits must be well worthy of study. Frequently the miners unearth tusks and bones of the mammoth, and I was informed by a miner that a human skull was found on bed rock 18 feet below the surface of the ground somewhere near the Forks. The skull may have been buried by a landslide, but if not, a study of the locality by a competent person might throw some valuable light on the question of the age of man on our continent.

It seems probable then that men in their search for gold, like the farmer's sons in the fable, may bring to light riches of an unlooked for sort, in the realm of knowledge.

CANADIAN STEAM RAILWAYS.

C. B. Smith, Ma.E. (McGill), M. Can. Soc. C.E.

Doubtless you all know something about railways, and no one knows all about them, but between these limits there is room for considerable study.

I desire to direct your attention first of all to the extreme importance of any Canadian engineer, no matter of what department of the profession, possessing a clear, general understanding of this railway question as it affects the nation, as it affects industrial matters, and especially as it affects his own particular branch of the profession.

Realize for a moment the interests involved:—The Canadian system of railways has a gross capitalization of $950,000,000, an actual investment of perhaps $700,000,000 hard cash, or from one-eighth to one-tenth of all our national wealth. It does a yearly business of $60,000,000, and employs directly 60,000 to 70,000 men, besides the many thousands whose livelihood depends on its operation. The railway is with us, as with other civilized nations, at the very basis of our prosperity, having become essential to our present mode of life, indeed it has been the means of causing a congestion of population in manufacturing and commercial centres, and has rendered a widespread production and distribution of food, forest, and mine products possible over vast inland districts that would otherwise be yet practically dormant and uninhabited.

It appears to me that the railway, in general, is the central and vital feature of the industrial progress of this century, and a ruling factor in the progress of a nation.

Canadian railways, like those of the United States, began on the same general lines as those of Great Britain, a few small English engines were sent over, but the civil engineers of from 1830 to 1840, soon saw that new conditions demanded new methods, and since then the progress of our railway development has been similar to

that of the United States. A continent was to be developed and the means at hand limited so that many economies were devised, and are even yet practiced, all justifiable when the ends in view are considered.

It was soon found that engines could haul trains on much heavier grades than had been used in England. The use of swivelling trucks and equalizing levers enabled much sharper curves to be freely introduced. Timber also was, and is yet, freely used for even important structures. The result of this cheaper system of construction, and the very slight charter, legal, and right of way expenses, and also of the fact that most roads in America even to the present day are single track is, that the capitalization of Canadian railways is only one-quarter of that of English ones, and the bonds and preferred stock only about one-fifth. (See Table I.)

It is evident that making allowance for a few roads which have more than one track, that the class of road is very much the same in the U.S.A. as Canada.

The justification for this great discrepancy in first cost is that the English railways have an enormous *traffic revenue in sight*, and capitalists there can figure pretty closely what the revenue of a given route is going to be. This enormous revenue of $20,000 per mile per year is partly a result of the traffic offered and partly from the high freight charge of 2 cents per ton mile.

It is apparent that this high charge is partly justified by the shortness of the haul, which makes the terminal charges bear a large proportion of the total; but the light loads, and small four-wheeled freight cars, high speeds and frequent trains, must share the onus of this high charge. (See Table II.)

The development of heavy engines, heavy loads, capacious freight cars in which the dead load forms only 30 to 40 per cent. of the total, and moderate speeds, along with the long haul, has brought about a very low freight charge in America, being (Table I.) $\frac{3}{4}$ cent per ton mile in U. S. A., and not much higher in Canada. On the other hand, Canadian traffic revenue is very light, only $3,000 to $3,500 per mile per year, partly due to moderate charges, but chiefly to sparse population. Although, unfortunately, our freight and passenger charges cannot be precisely determined, as there is a crucial deficiency in the traffic returns made by the railways to the Government, namely:—The ton-miles, and passenger miles. Until

TABLE I.—RAILWAY STATISTICS, 1895.

CAPITALIZATION, FIXED CHARGES, WORKING EXPENSES, EARNINGS, ETC.

ITEM.	CANADA.		GREAT BRITAIN.		UNITED STATES.	
	Total.	Per Mile.	Total.	Per Mile.	Total.	Per Mile.
Mileage	16,091	.....	21,174	.....	180,657	.....
Population	5,100,000	317	39,300,000	1,856	69,000,000	¶382
Square miles	1,609,000	.....	120,800	.....	2,970,000	¶
Population per square mile	3.2	.....	325	.....	23.2	.....
Capitalization.						
Bonds	$330,786,000	$20,557	$1,800,906,000	$85,000	$5,407,000,000	$30,000
Preferred stock	105,680,000	6,568	1,236,446,000	58,400	759,000,000	4,200
Common stock	255,769,000	15,897	1,772,862,000	83,700	4,961,000,000	27,400
Loans and floating debts	37,626,000	2,338	67,196,000	3,100	616,000,000	3,500
Bonus and Government aid	167,523,000	*10,411	.....	.....	.....	.....
Total	$897,384,000	$55,761	$4,875,410,000	$230,200	$11,743,000,000	‖$65,100
Earnings, Etc.						
Passenger	13,311,440	827	181,949,000	8,593	252,000,000	1,390
Freight	29,545,490	1,836	214,450,000	10,033	730,000,000	4,040
Other	2,928,560	245	22,044,000	1,136	93,000,000	515
Total	$46,785,490	$2,908	$418,443,000	$19,762	$1,075,000,000	$5,945
Working expenses	32,749,670	2,035	233,159,000	11,011	726,000,000	4,020
Net earnings	$14,035,820	$873	$185,284,000	$8,751	$349,000,000	$1,925
Per cent. working expenses to gross earnings	.70	.....	55¾	.....	67½	.....
Per cent. net earnings to total capitalization	1.56	.....	3.80	.....	2.97	.....
Fixed Charges.						
Bond interest	*$15,287,250	(4.62%)	‡$121,494,000	(4%)	$240,000,000	(4.42%)
Other interest on loans, rentals, etc	†1,881,300	(5.0%)	‡ 2,688,000	(4%)	53,000,000	.....
Total	$17,168,550	.....	$124,182,000	.....	$293,000,000	.....
Net income	— 3,132,730	.....	61,104,000	.....	56,000,000	.....
Stock-bearing dividends	.....	.....	1,538,920,000	.....	1,716,000,000	.....
" not "	.....	.....	233,760,000	.....	3,245,000,000	.....
Dividends declared	.....	.....	61,104,000	.....	85,000,000	.....
Taken from surplus, or borrowed	.....	.....	.....	.....	29,000,000	.....
Passenger charge per mile	Estimated 2.5c	.....	2.1c.	.....	2.07c.	.....
" per ton-mile	" 1¼c	.....	2.0c.	.....	.81c.	.....
Earnings per passenger train-mile	87c	.....	99c.	.....	.77c.	.....
" " freight "	$1.48	.....	$1.43	.....	$1.49	.....
Average cost per train-mile	80½c	.....	64⅝	.....	87c.	.....

*Includes 4½ per cent. on $14,212,000 bonds of which rate of interest is not obtainable. †Estimated at 5 per cent. ‡Estimated at 4 per cent on bonds and preferred stock. § Not including extra tracks. ¶ Only explored regions of Canada are counted in this calculation. ‖U.S. stock heavily watered.

TABLE II.- RAILWAY STATISTICS, 1895.

TRAFFIC, EQUIPMENT, ETC.

Item.	Canada.		Great Britain.		United States.	
	Total.	Per Mile	Total.	Per Mile	Total.	Per Mile.
Gross earnings per inhabitant	$9,00	.....	$10,60	.....	$15,60	
Passenger Traffic.						
Number of passengers	13,987,580	870	930,967,000	43,900	543,000,000	3,066
Passenger cars	1,994	$1\frac{2}{10\,0}$	42,230	2	33,112	$\frac{18}{10\,0}$
Average haul (miles)	38*	.....	8	.....	23	
Average load	3 *	.....	49	.....	39	
Passenger cars per 1,000,000 passengers	143	.....	45	.....	65.	
Passenger train miles	15,332,276	.....	184,200,000	.....	327,294,000	
Passenger trains per day (each way) †	$1\frac{1}{4}$	.....	12	.....	$2\frac{1}{2}$	
Freight Traffic.						
Tons of freight	21,524,421	1,340	334,230,000	15,800	763,0000,000	4,230.
Freight cars	52,118	.....	603,710	.....	1,196,119	
Average haul (miles)	110*	.....	35	.....	116.	
Average load (tons)	119*	.....	73	.....	180.	
Freight cars per 1,000,000 tons	2,421	.....	1,806	.....	1,717	
Freight train miles	19,939,699	.....	150,400,000	.....	491,410,000	
Freight trains per day (each way) †	$1\frac{7}{10}$	.....	$9\frac{7}{10}$	.....	$3\frac{7}{10}$	
Mixed Traffic.						
Various kinds of cars ‖	5,999	.....	31,088	.....	41,330	
Mixed train mileage	5,389,915	.....	4,300,000	.....	15,457,000	
Mixed trains per day (each way) †	$\frac{1}{2}$	.....	$\frac{3}{10}$	.....	$\frac{1}{8}$	
Total trains per day (each way) †	$3\frac{46}{10\,0}$	.....	22	.....	$6\frac{35}{10\,0}$	
Engines.						
Total number	2,023	.....	18,658	.....	35,111	Including switching engines.
Average yearly engine mileage ‡	20,100	.....	18,160	.....	23,760	
Employees	55,000	.....	465,112	22	785,000	$4\frac{4}{10}$
" killed	50	.....	442	.....	1,811	
" injured	488	.....	2,654	.....	25,693	
Passengers killed	9	.....	83	.....	170	
" injured	60	.....	1,109	.....	2,373.	
" killed, 1 in	1,554,000	.....	11,202,059	.....	2,984,000	
" injured, 1 in	233,126	.....	838,387	.....	213,000	

* Based on assumed average passenger and freight rates. † 365 days in a year. Train each way called "one train per day."
‡ Including switching engines. ‖ Express, Baggage, Postal, Sleepers, Dining Room, Transportation Co.'s Cars, etc.

this is done, as it is in the U. S. A. (but not in England), no strictly intelligent study of the subject can be made; yet, judging by the best evidence bearing on it, and the U. S. A. railway returns, it is probable that the average Canadian freight charge is not more than 1¼c. per ton mile, which is quite moderate by comparison considering the light traffic obtainable.

There is much evidence that in America at least, traffic revenue increases much more rapidly than the population tributary per mile of railway. A. M. Wellington, an authority on this subject, adduced various data to show that it increased as the square of the population served. By which we can see how very, very, important a matter the location of a railway is, striking at the root of the enterprise for success or otherwise, given a certain position however, the revenue will vary with other causes, prominent being competition and the pursuits of the inhabitants of the various districts passed through. The average is $10 to $11 per head per year for Canada, but is much less in rural parts and in country towns inhabitated by retired merchants and farmers, and much more in industrial centres as Galt, Peterboro', Hamilton, Woodstock, etc. Increase of traffic 5 per cent. per year in east; 10 to 15 per cent. in west, if well located. Good or bad judgment, however, in location is often the deciding feature, looking on the railway as a business concern established for the purpose of selling transportation; as it is a unique enterprise, having nearly all its capital locked up in an unsaleable form, and cannot retire from business.

It must be a very feeble recently built town that will move to a railroad, usually a town whose centre is one or two miles from its railway, unless otherwise served, languishes, and the total result is stagnation and loss to all concerned. Some railways in seeking after that silliest of boasts, "long tangents," leave thriving towns to one side; other towns will not come down handsome in bonusing and are given the go-by, while in some few cases, a town is on such a hill or in such a valley as to be out of reach of any railway having regard for its grades. But we may take it as an axiom that—giving due weight to directness of route and total length, the key note in location is to link together the greatest aggregate population by passing through the *very heart* of centres of population.

Another point which the two great Canadian railways illustrate is the cumulative value of branch traffic brought on to the main line.

Branches themselves often do not pay dividends, but are or may be bought or built to fight rivals, or shut them out, and always with the idea of feeding the main line, in which case it is estimated that, placing the cost of handling a unit of traffic on the main line at 100 per cent, *extra* train loads can be handled for 50 per cent., extra car loads at 10 to 25 per cent., and extra passengers or parcels of freight for not more than 5 per cent. The reason being that only some of the items of expense of operation vary with slight increases of traffic, e.g., (Table III.)

Traffic revenue increased from $2,910 with $2,040 working expenses in 1895, to $3,540 with $2,320 working expenses in 1898, or from 70 per cent. to 65½ per cent, which means that $630 of traffic was handled by an expenditure of $280, or about 45 per cent. in place of 65 to 70 per cent. for the whole traffic. There are many interesting points to be taken from Table III. The net income has changed from a *minus* to a *plus* in 3 years, by increased traffic—there is some money to pay dividends to stockholders with, and to increase the rolling stock and make the structures and roadbeds more permanent.

Also notice that 1895-96, being bad years, the bonded debt per mile has increased, in other words, floating debts were liquidated by selling fresh bonds in 1897 in the face of a cheaper class of roads being built. Also that the earnings per inhabitant and engine mileage, per engine, have largely increased, but that the cost and earnings per train mile does not vary much.

(Note the poor character of railway holdings, as a whole, as investments, as shown by percentage net earnings are of gross capitalization.)

Having touched on the subjects of railway investments and traffic, the natural sequence will be to deal with the cost of operation. This cost will depend on the relative volume of traffic offered, and on the physical characteristics of the rolling stock and roadbed, the ability of the operating staff, and on the ruling and other grades of the road, and the amount of curvature. If we assume a certain traffic being offered, then the ruling grades and weight of engines used are the important factors. The load which a given engine can haul depends on the grades, curves, and condition of track.

For moderate speeds the resistance offered on a level, straight track is 5 to 7 lbs. per ton in summer, and 7 to 9 lbs. per ton in

TABLE No. III.—CANADIAN RAILWAYS.

STATISTICS FOR 1895, 1897, 1898.

ITEM.	Total.	Per Mile.	Total.	Per Mile.	Total.	Per Mile.
Mileage	16,091	.....	16,687	.....	16,870	.....
Population	5,100,000	317	5,300,000	318	5,400,000	320
Square miles	1,600,000	.....	.....	.....	.....	.....
Population per square mile	3 2-10	.....	3 3-10	.....	3 36-100	.....
Capitalization.						
Bonds	$331,000,000	$20,600	$349,000,000	$20,900	$355,000,000	$21,000
Preferred stock	106,000,000	6,600	107,000,000	6,400	111,000,000	6,600
Common stock	256,000,000	15,900	260,000,000	15,600	267,000,000	15,800
Loans, etc	37,000,000	2,300	37,000,000	2,200	39,000,000	2,300
Bonuses, etc	167,000,000	10,400	173,000,000	10,400	178,000,000	10,500
Total	$897,000,000	$55,800	$926,000,000	$55,500	$950,000,000	$56,200
Earnings.						
Passenger	$13,300,000	$ 830	$13,900,000	$ 840	$15,600,000	$ 930
Freight	29,600,000	1,840	33,500,000	2,010	38,500,000	2,280
Other	3,900,000	240	4,900,000	290	5,600,000	330
Total	$46,800,000	$2,910	$52,300,000	$3,140	$59,700,000	$3,540
Working expenses	32,800,000	2,040	35,100,000	2,110	39,100,000	2,320
Net earnings	$14,000,000	$870	$17,200,000	$1,030	$20,600,000	$1,220
Fixed Charges.						
Bond interest	$15,300,000	4 62-100%	$16,000,000	4 60-100%	$16,300,000	4 6-100%
Interest on loans and rentals	1,800,000	5%	1,850,000	5%	1,980,000	5%
Total	$17,100,000	.....	$17,850,000	.....	$18,280,000	.....
App. net income	— 3,100,000	.....	— 650,000	.....	2,320,000	.....
Per cent. working expenses of gross earnings	70	.....	67	.....	65½	.....
Per cent. net earnings of gross capitalization	1 56-100	.....	1 85-100	.....	2 16-100	.....
Pass. charge per mile, estimated at 2.5c. per mile on average.						
Freight charge per ton-mile, estimated at 1.25c. per ton-mile on average.						
Earnings per passenger train-mile	.....	$0.87	.....	$0.80	.....	$ 0.81
" freight "	.....	1.48	.....	1.42	.....	1.43
Average cost per train mile	.....	0 80½	.....	0.77	.....	0.77
Gross earnings per capita	.....	9.00	.....	9.90	.....	11.05
Average yearly engine mileage	.....	20,100	.....	20,100	.....	23,400

winter, and increasing rapidly for high passenger speeds and at the instant of starting, grade resistance is, of course, 20 lbs. per ton for 1 per cent. grade and varies with the grade.

Curve resistance is about ½ lb. per ton per degree curve and varies almost directly with the sharpness of curve. If we sum these up for the worst or ruling point on the road, it is easy to determine how much each given engine can haul, and thus the number of trains per day to handle a given traffic. An engine can exert a pull of about 33 per cent., 25 per cent., or 20 per cent. of the weight on its drivers on sanded, ordinary, and wet rails respectively. And this indicates at once the natural manner of increasing the trainload and thus economizing in freight haulage by increasing the weight on the driving wheels; but as a given track can only stand a certain wheel load without injury, the limit in this direction was soon reached, and has for many years been only slightly increased as the improved condition of track would warrant.

The inventive American engineer, civil and mechanical, soon saw that the opportunity lay in increasing the number of driving wheels, and thus gaining weight without injuring the track by undue concentration, and being able to go around sharp curves by omitting the flanges on some of the driving wheels, we have obtained in this way many types of freight engines, which show the successive stages of advancement. You will at once see, however, that there are various things that conspire to bring this process to an end. The length of driving wheel base is soon reached, and the weight allowable per wheel depends on the condition of track, weight of rail and strength of bridges, etc. So that practically each road has to decide on its own class and weight of engine for freight work, and govern its train loads accordingly.

An increase of traffic therefore may be met in two ways, first, by increasing the weight of the engines, and this is the more economical, as it will only affect about 15 per cent. of the working expenses. But when the second alternative of an increase in the number of engines and train loads is necessary, it is a much more serious matter and affects fully 50 per cent. of the working expenses of a road, from which it is evident that in comparing two or more routes, the most important factors are three in number: 1st. The traffic obtainable, regulating the income. 2nd. The cost of construction, regulating the fixed charges. 3rd. The cost of operation,

largely controlled by the number of train loads necessary for a given traffic, and therefore by the ruling gradient, e.g., let us suppose two routes of known traffic and cost of construction are to be compared, on which the ruling grades are $\frac{3}{4}$ ft. per 100 and 1 ft. per 100. (compensated. Then the hauling resistances are as 8+15 lbs. to 8+29 lbs., or $\frac{23}{15}$. Presuming a traffic of five freight trains per day on the lesser gradient, the one with the greater one will need $\frac{23}{15} \times 5 = 6$ trains; now 1 train per day additional each way for a year will cost about 80c. $\times$ 50 per cent. $\times$ 2 $\times$ 365 = \$292 per mile= 5 per cent. on \$5,840 per mile, a very respectable difference in capitalization, which could be spent on construction or roadbed alone beneath ballast and still leave the enterprises on an equal footing, not to speak of the increased advantage which would accrue in the future to the road having lighter grades as the traffic increased. We must not, however, lose sight of the fact that very few roads when first started have such a traffic as I have mentioned, perhaps one or two partly filled freight trains and one passenger train per day will handle all the traffic offered, and then differences of grade or curve are not important. These matters assume greater importance as the traffic increases.

This leads me, in conclusion, to say that herein lies the value of an educated civil engineer as regards railway matters. That in the preliminary study and location, the constitution of this enterprise is being formed and the most important stage in its history is being considered. The railway affords occupation, or is an instrument in the hands of every branch, almost, of our profession. The civil and mechanical engineers build it, maintain it, and operate it; mining engineers look on it, in its cruder forms, as a crucial instrument in the development of mines and properties; and to the chemist we must look for an appreciation of the qualities of lubricants, steel rails, and car wheels, etc. I am aware that special knowledge of some narrow department will be of greater value to young men just entering in pursuit of employment and promotion, but I urge on you that of most ultimate advantage will be a broad generous study of a railway as a business enterprise. To rise to the highest positions you must be more than engineers, you must be business men, and versed in railway economics, therefore consider this great subject from as many standpoints as you can before the cares of office and narrowness of concentrated effort make it more difficult and less likely.

ROADMAKING.

A. W. Campbell, C. E.

The vast importance of country roads as a factor of transportation has been far from understood by the people of this country. Effort has not been spared in completing the system of canals and railways, at a cost of millions of dollars, yet the deplorable condition of the common highways, so essential to the development of agricultural resources, has passed almost unnoticed, until very recently. No extraordinary effort has in any way been made towards their improvement, and in many cases, so far from being better, they have been going from bad to worse. It is sincerely to be hoped that the day of this lethargy has passed, and that we are entering upon a more enlightened era in this respect, as in many others.

The present aspect of the road question is distinctly evolutionary. Ever since the founding of this Province the statute labor law has been in force, requiring every farmer to work a certain number of days on the roads adjacent to his property; the number of days being in proportion to the assessed value of his land. This work is directed by a farmer appointed by the township council, to superintend the work on every mile and a half or two miles of road. The township councils have been in the habit of making money appropriations, but these have been spent on the statute labor basis, scattered and misapplied, without any semblance of expert direction. The methods applied to their construction and maintenance are plainly reflected in their condition.

But the period of neglect is, we believe, giving place to something better. Statute labor is passing into disrepute, and a better appreciation of the value of good roads is springing up. The central governments are taking a more active part in their improvement. County Councils are exhibiting a greater interest, and in every respect the outlook for a more intelligent management of

country roads is encouraging, and the time is no doubt approaching when the care of roads, with bridges, culverts, and all that pertains to them, will offer a field for engineering employment, as is the case with England, Germany, France and the more advanced European countries.

It may be said that it will be a good many years before expensive roads, such as are made in the countries named, can be afforded by the sparser population, and less wealth of Ontario. While this is true in the main, nevertheless there are some roads such as Yonge Street, leading north to Lake Simcoe from Toronto, which could now be profitably built in the best manner. And even if the great majority of roads will receive comparatively inexpensive treatment, there is all the more reason, perhaps, for the best of engineering skill, in order that the means available for roads may be applied in the most economical and skilful manner so as to secure the best results from the limited expenditure.

The construction of a good gravel or broken stone road is largely a matter of good drainage. Almost every detail can be discussed as a matter of drainage. We make open gutters at the side of the road to carry away surface water. We place tile underdrains wherever they are needed to carry away sub-soil water, and secure a firm foundation. We round or crown the travelled roadway so as to throw the water from its surface to the open gutters. The travelled track, we cover with broken stone or other metal largely to form a water-proof covering, that will prevent moisture passing through and softening the sub-soil beneath so that it will not support the weight of a load.

The importance of keeping the roadbed dry cannot be too thoroughly impressed. Clay in thick beds, when dry, will support from four to six tons per square foot of surface, according to the quality of the clay. If only moderately dry it will support only from two to four tons per square foot of surface. If the clay is wet and soft it will yield to almost any load. Gravel, if well compacted, forms a much stronger roadbed, is less yielding to the action of moisture, and for this reason even for a thin surface coating, strengthens the road somewhat. But the real strength of the road must lie in the sub-soil. Vegetable moulds and alluvial soils are weak, having a sustaining power of only one-half to one ton per square foot, and

for this reason it is well to remove such soils, securing if possible, a gravel, clay, or sand foundation.

A porous soil, like a sponge, retains in its texture, by capillary attraction, a certain amount of water. When water in excess of this is added it sinks to the first impenetrable strata, and from there it rises higher and higher until it finds a lateral outlet; just as water poured into a pail will rise higher and higher until it finds an outlet in the side of the pail, or until it flows over the top. Underdraining supplies the necessary outlet for this excess moisture at a proper depth from the surface; "it lowers the water line."

With plastic clays the process is slightly different. Clay will absorb nearly one-half its bulk and weight of water. In drying it shrinks and is torn in different directions. The fissures commenced by a tile drain become new drains to lead water to the tile; and so the process of contracting and cracking continues until a network of fissures is produced, and the stiffest clay is thereby drained.

The injury done to roads by frost is caused entirely by the presence of water. Water expands on freezing, and the more there is under a road, and above frost line, the greater is the injury. The particles of soil in immediate contact with the water are first compacted. When room for expansion ceases within the body of the soil itself, the surface is upheaved. When thawing takes place the sub-soil will be found honey-combed, ready to settle and sink beneath traffic. It is therefore of the utmost importance that the soil should be relieved of the water of saturation as quickly as possible by under-drainage. The impassable condition of most roads in Canada during the spring, often axle deep in mud, is to be attributed very largely to a wet sub-soil which has been honey-combed by frost.

It is difficult, indeed impossible to lay down rules in detail for the construction of a road. There are principles which may be enunciated, which can be applied in every case; but the method of applying them differs to a greater or less degree in each piece of work undertaken. There must be good judgment, based upon a knowledge of the materials with which you have to work.

We have said that good drainage is the first principle of successful roadmaking. This, nevertheless, must be accepted with dis-

cretion. Something depends upon the location of a road. If it is upon an elevated ridge, it may be that natural drainage is sufficient with very little further attention. While if it passes over low swampy ground, the best of artificial drainage will probably be necessary. A great deal depends on the kind of sub-soil. If it is a stiff clay, any drainage that can be afforded may not be thrown away. If it is a loose gravel the need for drainage will not be so great. If it is a light sand the less drainage, in all probability, the better.

In nearly all roads there are certain points springy and spongy, which should be tapped by blind drains leading from the centre of the road diagonally to the sides. These would empty into the first watercourse available; or into side under-drains, if they exist. The usual form of complete under-drainage consists of two tile drains, one on each side of the roadway, beneath the open gutters into which these diagonal drains will discharge.

But a complete under-drainage of this kind will cost about $500 per mile, so that it is usually advisable to curtail it as far as possible. In the case of sand it might be a positive injury rather than otherwise. Sand to present its greatest strength as a foundation requires a certain amount of moisture. The surface of an asphalt roadway consists chiefly of a body of sand held together by the mineral pitch asphalt, which is a material following the laws of a liquid. In the same way a certain amount of water in sand helps to solidify it. In view of this there should be under-drainage only where the signs of springs or other underground waters appear, and the open drains should not be placed at too great a depth. Along a sand road, too, it is well to plant trees, to shade and assist in retaining moisture, the elm being one of the most suitable for this purpose, as there is a happy medium even in the matter of shade.

In regard to the metal, the gravel or broken stone used on the road, it is usually necessary to choose the best and make the best of the local supply. An acquaintance with geology and mineralogy can readily be used to advantage in this regard. We must first, however, consider the main qualities demanded as a paving material. The stones forming the road covering should be tough rather than hard; for if they are hard they are likely to be brittle, and readily broken by the impact of a horse's shoe, and the weight of the load

applied through the wheel. A tough stone will resist the hammering, grinding and bending tests to which it is subjected more successfully than will a very hard stone. Not only should a stone be tough to resist wear, but it should possess the quality of binding and compacting so as to form a smooth, water-proof surface covering for the road.

Trap rock is placed at the head of materials for broken stone roads. This is tough, hard, and has excellent wearing qualities. Granite is hard, but lacking in toughness, and does not bind readily. Limestone possesses the best binding qualities. The dust formed in the original crushing and by subsequent altrition, becomes a species of cement, which set and re-sets, and results in a very water-proof covering. Some kinds, however, are too soft for economical use, and this inability to resist wear makes the stone, except in particularly tough varieties, unsuitable for heavy traffic. Gravel is an excellent material for light traffic, particularly that formed from the harder Laurentian rocks, found in the eastern part of the Province. It must, however, be free from an excess of clay, loam or earthy matter, otherwise it will not assume a bond that will withstand traffic in wet weather.

With roadmaking as in nearly all branches of construction, improved machinery and implements are beginning to take a very prominent place. Until very recently the old drag scraper in addition to the common plow, and the ordinary farm wagon, with pick and the shovel, were the only tools employed on Canadian roads. Recently, however, wheeled scrapers, road graders, rock crushers with screen attachment, steam and horse rollers have been introduced.

The road grader or grading machine, is now used by about one-half the townships of the Province. They are used, as the name indicates, for grading the earth roads; that is, drawing the earth from the gutter and bringing it to the centre of the travelled roadway, to form a crown, on which the gravel or stone is placed. This is, of course, the cheapest kind of road construction, but is the plan now followed in our country districts. The grader is turned to account in repairing roads, using it as a scraper; or in cutting off the shoulders which form by the flattening out of the roadway through the washing down, and forcing down of the crown. These

shoulders, consisting of sand, earth and turf, should never be restored to the crown, but should be thrown outward, and the crown of the road restored by the application of new material.

The road graders are commonly operated by horse power, from two to six, usually four, horses being required according to the nature of the work. Better than this, a traction engine will provide a more constant draft, and although somewhat slower than horses, makes up for this in the time horses will need for rest. In addition, the operation by traction engine is usually cheaper than with horses.

The rock crusher is coming into more general use, although not more than thirty Ontario municipalities use them as yet. Where there is a great quantity of field boulders available for road metal, a small crusher which, can be mounted on wheels and moved from place to place throughout a township is very useful. If the stone is taken from a quarry, it is better to use a larger stationary crusher.

There should be attached to the crusher a rotary screen. This will grade the stone into various sizes, such as stone, dust and chips, $\frac{3}{4}$ inches diameter; $1\frac{1}{2}$ inches diameter; $2\frac{1}{2}$ inches diameter. When graded in this way the coarsest stone is placed in the bottom of the road, and the finest on top, the screenings of dust and chips being mixed through all the courses to fill the voids and assist in forming a bond. A crusher is very useful, too, in preparing certain forms of gravel. If there are many large stones they will be broken to a proper size, and if there is an excess of sand or earthy material, this will be removed by the screen. In operating a crusher, a traction engine is frequently employed, and if it is a movable crusher, the engine can be used for taking the crusher from place to place. If it is a stationary crusher, a stationary engine will be sufficient, although it may be advisable to have a traction engine for operating the grader, which can then be used for both crusher and grader. In towns where electric power is available for a stationary plant, an electric motor is the cheapest and most convenient power.

The steam roller is, wherever a municipality can afford it, one of the most useful implements that can be used on the road, particularly where broken stone is the metal employed. Unless a roller is used, the stone must be spread loosely on the road, and left for

traffic to consolidate it. This is a slow process, causing much inconvenience to travel, and during which the earth sub-soil and stone become largely mixed, thereby destroying greatly the durability of the road. Earth mixed with stone, as previously pointed out, prevents the strong mechanical bond which clean metal will assume, when the stones are wedged one against another. The earth, however, prevents largely this mechanical bond, softens in wet weather, and the surface is then more readily broken up.

By the use of a roller, the earth sub-soil should first be made compact and solid. In this way a smooth, durable, waterproof coating can be laid over a firm sub-soil. The use of the roller does not end here. When re-surfacing old roads, picks or teeth may be inserted in the roller. These passed over the road loosen the old surface, which can then be readily worked up still more, either by hand labor or the use of a weighted harrow. The new stone can then be placed on this roughened surface, and the whole again rolled down, the old and new metal being thoroughly bonded together.

In a brief review of some of the principal features of roadmaking, there is constantly a tendency to follow the stereotyped details of construction which are more fully dealt with in the various text books on the subject. In the present article, it has been my wish to indicate the class of practice which will be met with for some years to come in Ontario. When this, however, is thoroughly understood, there will be little difficulty in adapting this knowledge to the more permanent Macadam and Telford systems which will gradually be required with increased population and traffic.

VENTILATION AND HEATING OF PUBLIC BUILDINGS.

P. H. Bryce, M.A., M.D.
Secretary, Provincial Board of Health.

Mr. President and Gentlemen of the Engineering Society:

In my addresses to you in the several past years, I have endeavoured to deal with some practical subject in public health work, which you as engineers and architects may be expected to have to deal with. We have drained the ground upon which we were going to build a house; we have carefully considered the source and means of preserving its drinking water in a wholesome condition, and have also set forth in some detail the several means which modern science has supplied for properly dealing with the excretal matters which, as sewage, require removal from such a human habitation.

To-day I propose to deal with another feature of the sanitation of this house, viz., that of the house-air and the means whereby it may serve the requirements of health to its inmates.

It is safe to say that while there has been progress in the work of constructing buildings and in the mechanical appliances for heating them, and even ventilating them, in many individual instances during the past fifteen years, yet there is probably no branch of public health work which has shown so little progress in its systematic development in Ontario as of those methods of heating and ventilation, which even in the most general way, have official sanction and are governed by either legislative or municipal regulations. If one were to seek for an explanation of this it would probably be found: *First*, in the very nature of the problem. It must be remembered that the moment life in buildings with closed sides began in climates requiring artificial heat, it became artificial. "The wind bloweth where it listeth" are the words of the Teacher, applicable to the free movements of the outer atmosphere only, and all attempts

to confine air and heat it necessarily cause a departure from nature's methods and convert the problem of supplying the dwellers in houses with fresh air into a question subject to the limitations of a *secundam artem*. A *second* reason is that from the very nature of the complex life of any population living in populous centres, there are not in Ontario as yet any regulations fixing in any definite way the size, mode of construction or number of inmates of houses, except where it is stated under the Factory Act that—

Section 15.—(2) "A factory shall not be so overcrowded while work is being carried on therein as to be injurious to the health of the persons employed therein.

"(3) Every factory shall be ventilated in such a manner as to render harmless, so far as is reasonably practicable, all the gases, vapors, dust or other impurities generated in the course of the manufacturing process or handicraft carried on therein, that may be injurious to health."

As the Act states, however, these necessary and reasonable provisions shall not apply where persons are employed at home, that is to say to a private house, or a room or place which, though used as a dwelling, might by reason of the work carried on there be a factory within the meaning of the Act, and in which the only persons employed are members of the same family dwelling there.

It is further provided in the school regulations that public schoolrooms shall have an air space of not less than 250 feet per pupil, with a superficial area of at least 12 square feet, a uniform temperature of 67° F., and provision for a change of air three times every hour.

And a *third* reason is the lack of well-defined methods of ventilating public buildings, readily applicable to different buildings, arranged so as to secure at a moderate expense an adequate supply of fresh air in such a manner as to be free from draughts.

It will thus be seen that the problem of maintaining house air in a condition of purity necessary to make it in some degree comparable to that of the outside air is in practice a difficult one, judging from results; but nevertheless, when it is remembered that an adult man requires 3,000 cubic feet of fresh air per hour, introduced into his living room in order that such air may be maintained at a

point where the carbonic acid produced by combustion in the lungs shall not exceed six parts in 10,000 of air, it is apparent that the evils due to lack of ventilation in private dwellings, public buildings and factories, are one of the most serious sanitary questions existing in our communities. The adoption of some artifical or mechanical means for the purpose of introducing fresh air into dwellings is commonly termed "ventilation," and depends upon some method whereby the air of a room may be removed and replaced by outside air, which, owing to its free movements, always maintains practically the same constitution. This is understood when it is remembered that air moving at the rate of five miles an hour, or that of the gentlest breeze, will renew the air over a space of a foot square 26,400 times. In warm weather ventilation is easily possible by doors and windows, but in cold weather air must be introduced into rooms through ducts, having been previously warmed by a furnace.

From the standpoint of the public, there is no doubt that apart from a lack of knowledge of the directly injurious effects upon health of residence in badly ventilated houses, and of the existence of practical means of remedying the evil, the prime difficulty is that the individual recognizes by the eye no difference between the indoor and out door air. He can recognize closeness on coming into a foul atmosphere from outer fresh air, but this closeness is looked upon as inevitable, and the deadened sense of smell soon fails to recognize the foul odors. Moreover, the methods of heating and constructing houses vary so greatly that badly distributed warmth in houses makes people more anxious to confine the heat produced than to introduce fresh air.

Amid the questions of economy to the householder, of the architects who are specially sought out because of their ability to give a fashionable outside to houses, of competition amongst the innumerable manufacturers of furnaces, boilers, grates and stoves, all of which are *of course* modelled upon the latest scientific principles, it may be well to recall some of the laws underlying what seems so simple, and yet proves to be one of the most difficult practical problems which sanitarians, architects, and engineers are called upon to deal with.

To maintain the human body in a state of health, it must not only be supplied with an amount of food requisite for supplying it with energy for work, but it must also consume an amount equal

to the task of maintaining the body at a temperature of 98.4° F. As bodies lose their heat both by radiation and conduction, it is plain that non-conducting clothing plays an important part in preventing an undue loss of body heat; but common experience tells us that for persons employed at sedentary occupations in-doors, an air temperature of from 60° to 70° F., is necessary to comfort and health. Further experience tells us that the air of the room must not be in too rapid movement, probably not more than a half-foot per second, and must further be, as nearly as possible, as warm near the floor as at 6 feet above it. With the atmosphere in temperate climates ranging in winter between 30° F. and—20° F., it is plain that the amount of heat required to keep the air of a house warm, will depend (a) upon the construction of the dwelling, (b) upon the number of renewals of air per hour, and (c) upon the character of the heating apparatus employed. As regard the construction of a house, it is necessary that the walls be made of materials which are poor conductors of heat, that they may be so built that moisture will not readily get into the interstices of the materials, as with soft brick, unpainted boards, and damp foundations; and that they will be so well built of close materials that air currents will not blow through them. How essential that building materials be poor conductors may be learnt from the notably different conductivities of different substances for heat. Thus, a wall of wood of equal thickness would be three times better as a non-conductor, than one of brick. It is of equal importance to remember that air confined in a close space is ten times as good a non-conductor as wood, hence the important part played by double windows, glass being ten times better as a non-conductor than wood.

As regards the required changes in the air of the room, it is plain that as this will depend on its size and the number of its inmates, the amount of air to be heated will be simply that required to supply the ideal 3,000 cubic feet per hour to each adult inmate; while the heating apparatus to be chosen will be that which most readily transfers its heat with the smallest loss to the air supplied to the dwelling. While it may be said that, in theoretically discussing ventilation, we need not regard by what method the air to be supplied to a room is heated, yet in practice, the question is a most important part of any system. When carbon or its compounds,

whether as coal gas or wood is consumed, it produces heat by the union of carbon with oxygen, while hydrogen at the higher temperatures if present, unites with oxygen to form water vapor. In combustion every pound of carbon forms 3.7 lbs. of carbonic acid, and emits heat enough to raise the temperature of 87 lbs. of water from 62° to 212° F. and every pound of hydrogen produces 9 lbs. of water, and emits enough heat to raise 417 lbs. of water from 62° to 212° F. For the purpose of estimating the value of any fuel, it is most convenient to estimate the number of pounds of water which can be raised by any given weight of fuel, , though 1° F. or from 32° to 33° F. which is termed a *heat or thermal unit*, and which is roughly applicable for every degree from 32° to 212° F. Experiment has shown that 1 lb. of carbon produces 13,000 units of heat and 1 lb. of hydrogen produces 62,500 units. What then is apparent is that economy in heating means that the largest possible number of units of this heat, instead of being allowed to escape by the chimney, or other way, be transmitted directly or indirectly to the air of the rooms occupied; the air being in such a condition of purity and freedom from movements, and having such evenness of distribution, that a sense of comfort may be given to all the inmates.

The modes by which heat is transmitted to the air of a room, viz., by conduction, convection and radiation, all play their part, each being given a greater or less importance accordance as grates, stoves, furnaces, hot water or steam pipes be the method of heating adopted.

The following results, obtained by Profs. Carnelly and Haldane, of Dundee, Scotland, have much interest in this connection; but they are necessarily to be accepted not so much as indicating the value of any particular system as the mode of application of any of the systems accidentally adopted in those particular schools at that time.

Of 323 schools reported upon 150 were personally visited by Carnelly. The great differences were found in the amount of fuel used per pupil. One large school, with hot air furnace, used but 34 lbs. of coal per head in a season, while another used 417 lbs. One with an open fire used but 23 lbs., while another used 239 lbs. In a school for 1,000 scholars the cost in England averaged for installing the system £200 for grates and £500 for low pressure steam. The installation of a mechanical fan ventilating plant with heating cost in a building properly designed for it £850, and put in an old building

not specially designed cost £1,000. The results of experiments showed that mechanical ventilation as by fans was much the most effective in maintaining the requisite purity and temperature of the air; was more independent of winds and changing weather; reduced draughts to a minimum, but has a greater first cost and somewhat greater cost for maintenance; but in a town with several schools one janitor could supervise the apparatus in all.

A more recent and perhaps more representative series of methods of heating and ventilation are those found in the reports prepared under the superivision of the Chief of the District Police of Massachusetts, 1896, who has special charge of the work of boiler inspection, fire-escapes and the heating and ventilating of public buildings, factories and work-shops of the State. The several reports of this Bureau are of extreme interest, illustrating year by year an advance in the scientific supervision of public buildings. The report for 1896, referring to the ventilation of schools, says, "The practicability of ventilating schools admits of no doubt. It is as much a matter of exact knowledge as any problem in engineering or mathematics. It can be done by the aid of power, and may be accomplished by heated shafts or by fans; all dependence on natural ventilation should be abandoned. The system of mechanical ventilation can be relied upon with certainty. By mechanical means a steady inflow of pure air under all conditions and atmospheric changes can be secured. The extra expense for the power to move air should be recognized and met without question."

"When so many are enquiring how best to secure good ventilation in school and other public buildings, the correct methods gained by years of experience should be made known. In this matter of ventilation there are comparatively few who have made it a specialty and have felt it necessary to perfect their knowledge. The time has been reached when the importance of ventilation is generally appreciated, and there seems to be a willingness to do something for the health and comfort of the pupils in our public schools, and it would be a misfortune not to achieve some real progress."

"Good ventilation consists in the proper arrangement and distribution of the ducts of the incoming and the outgoing of the air, and their relation and correspondence with each other, so that the perfect removal of the foul air and the thorough diffusion of the fresh

air will be secured. How to supply the occupants of schoolrooms or crowded apartments with the proper quantity and quality of air has not always received the attention its merits demand. Something, however, during the past few years has been done towards an intelligent solution of the problem. To know how much air is needed for a given number of pupils in a schoolroom and to supply it by exact mechanical measurement is now no secret."

"In former reports I have explained some of the methods advocated and in operation in school buildings in the State. One of the methods or systems concerns itself only with supplying air, leaving it to make its way out through ducts provided for that purpose. This is done by means of fans or blowers forcing the air into the room. It is the plenum method. Another system or method advocated is directed to the extraction of the foul air by natural laws, requiring no mechanical means, depending upon the difference between the external and internal temperature, in other words, the tendency of warm air to rise."

"In our experience of the past eight years we have found that the interior temperature of foul-air ducts is practically the same as that of the room. The changes in the temperature are so frequent and the velocity of the wind so various, that, *unless additional heat is supplied to the duct*, the power of the duct or shaft to draw air from the room will fail in many instances to cause upward motion enough to be measured by the anemometer."

"The ways of adapting the means to the end in furnishing to and removing air from crowded rooms are not questions of experiment. The size of ducts, shafts, etc., their location in the rooms and their distribution are not at the present time severe problems. The questions, 'Shall the air be taken in at the floor or at the ceilings?' or 'Will an upward or downward movement in the air work to the best advantage?' have been settled upon principles which are available for the practical solution of the problem of ventilation."

"For the effective working of any system of ventilation, it is imperatively required that proper provisions should be *made to promote air currents in the right direction*, and first in the *fresh-air inlet*,—the supply of fresh, pure air from pure external sources. The size of this fresh-air inlet is of great importance. In many instances when provided in our public buildings it has been found to be too small.

The warming of the incoming fresh air should be considered at this point. Varieties of heating appliances are in use for the purpose of warming the air, two of which I will mention,—the hot-air furnace and the high-pressure or low-pressure steam apparatus."

The difficulties to be overcome by the adoption of any system depend upon the operation of the same principles. Heating by convection is due primarily to the movement of air upward, heated and by expansion made lighter, and falling again as it is cooled by walls and windows. By these currents of warmed air coming in contact with our bodies, we are prevented from cooling with undue rapidity in the same manner as by conduction the air of the room is cooled by the cold outer walls and windows. It will thus be apparent that with outer currents of air, as winds blowing against a building, the porosity or openness of the walls and the conductivity of the building materials and the doubling of the windows, must all play important parts in the ventilation and heating of dwellings. To minimize the variations of temperature caused by these several influences in different rooms and at different parts of the same room, to maintain the air at a temperature of 60° to 70° F., to secure a humidity of the air approaching 70 per cent. of saturation and to keep the carbonic air in the room at a point below six parts in 10,000, or to secure from thirty to fifty cubic feet of fresh air per minute for each inmate according to age, and to do this economically *is the problem of ventilation.*

This must be secured too in such a manner that the velocity at the inlets shall not exceed six feet per second, to be reduced to half a foot per second when coming in contact with inmates to prevent the sensation of draughts, although experiment has taught us that a velocity of two to three feet per second of air at an ordinary temperature may be endured without a sense of notable discomfort. How much this last point means will be understood, when it is remembered that a room containing 500 cubic feet of air having an inlet of twelve inches square, if supplying 3,000 cubic feet per hour, would have a velocity of .83 feet per second while supplying only enough air for one adult person. It is thus apparent that in order to maintain the requisite purity of house-air without an excessive air movement, a minimum air space fixed by some at 750 cubic feet per capita is necessary, thereby permitting some four changes of air per hour.

Apart from the question of heating and propelling the air into a room, it is equally clear that the size of fresh-air inlets and outlets is of primary importance in the question of the movement of the air. An illustration will make this evident. Assuming that properly warmed air can safely move at a rate of two feet per second without discomfort, and that the fresh-air inlet occupied a quarter of one wall of a square room thirty feet wide, it will have renewed the air in the room within two minutes, or thirty times in an hour. As this air is distributed over a space in the room in columns, four times the volume of that opposite the inlet, the general velocity in the room would be but one-quarter that at the opening, or six inches per second. If further the rate of renewal be lessened, it is apparent that the size of the inlet can still be notably reduced if the distribution of the air at the point of entry to the room is assisted by the shape of the inlet. Many of these elements which enter into the problem have been estimated, and even given their place in tables; but it is well that the various elements of the problem be recognized. This may be done by a single example.

A school house of four rooms, each to have a cubic-air space of 240 cubic feet (or 4x4x15) per pupil for a school of 200 pupils is to be heated and ventilated.

The construction of the building having been made upon the principles of building already indicated, we have to supply means of ventilation for supplying 2,000 cubic feet of fresh air per pupil per hour, or 100,000 cubic feet per hour must be poured into each room with cubic capacity of 12,000 feet. This means $8\frac{1}{3}$ changes of air per hour, or a renewal of air every 7 1-5 minutes. An inlet of 2 ft. x 2 ft. would deliver the requisite volume of air if moving at the rate of 6.94 feet per second. With the ordinary smooth ducts, as when lined with tin, to prevent friction as far as possible, it is estimated that from 20 to 25 per cent. is lost by friction, so that in the present instance the duct delivering air in the amount stated at the rate indicated should be about 2 ft. x 2.5 ft. in area. It is apparent that the forward movement of this volume of air will depend not only upon a steady motive power, a *vis a tergo*, by which, as with a fan, a regular pressure is maintained in the duct, thereby creating a plenum in the room, but also upon there being a free exit duct to conduct the air from the room, which removal of air can indeed be accelerated by

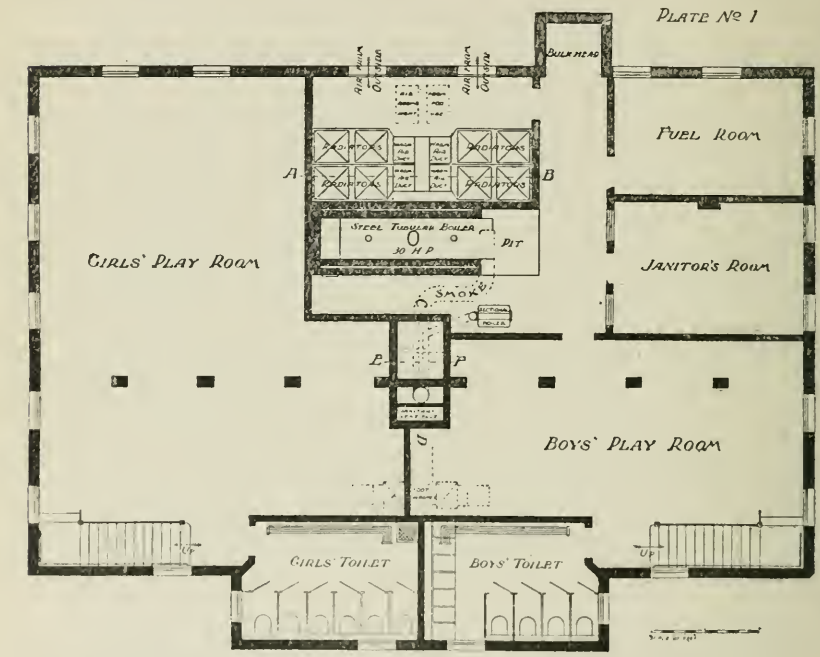
an exhaust fan at the outlet of the duct or by a coil of steam pipes in the exit shaft by which the air is heated and thereby made to ascend. Much experience in ventilating shafts by the officers of the Massachusetts Bureau leads to the conclusion that "as a rule, a reduction of one-fifth the area of the foul air outlets for the size of the fresh air inlets has proved sufficient for inflowing fresh air. I have seen no reason to change this statement, and it will be found that ventilating engineers and architects who have been the most successful in obtaining good ventilation have varied but little, if any, from the above rules." It is apparent that with the size of the inlets being determined as being, say 80, the outlet would be represented by 100. Along with the various elements as regards the size of inlets and outlets, it is important to have determined by experiment the most successful points at which inlets and outlets should be placed in any room, in order to promote the even distribution of the air introduced. Both English and American authorities are now agreed that in rooms of the ordinary size, as those in schools, inlets should be arranged on the inner walls, at a point from 6 to 8 feet above the floor, while the outlet should be at the floor in the same wall, and in close proximity to the outlet. This arrangement is based upon the fact that the incoming air is usually warmer than that of the room and therefore tends to ascend, and with the forward movement the impulse along with the higher temperature will distribute the fresh air to the farther side of the room; it being further aided by the lessened pressure caused by the downward movement of the chilled air along the outer wall, and the outward movement of this air along the floor to the outlet.

Summing up these points Mr. R. R. Wade of Boston, Chief of the Police Inspection Commissioners, says:

"Whatever differences of opinion may exist as to the merits of the various appliances that have been applied for the ventilation of schools or other public buildings, it must be admitted that the system that can furnish and remove under perfect control a sufficient amount of air, with a velocity that can be regulated and so distributed as to supply fresh air and remove foul air from each room with regularity and perfect independence of weather, summer and winter alike, should be the system to be adopted, and in all appliances that is the

simplest which most positively and directly effects the purpose in view."

The problem of heating the air equally has in every system proved of much difficulty in practice when a definite amount of fresh air is to be delivered. In estimating the work to be done, it is apparent that an average external temperature must be taken as the basis of ordinary work, and that for extremes a system of extra coils must



PLAN OF FOUR ROOM SCHOOL
DESIGNED TO SHOW
METHOD OF VENTILATION
BY DESCRIPTION

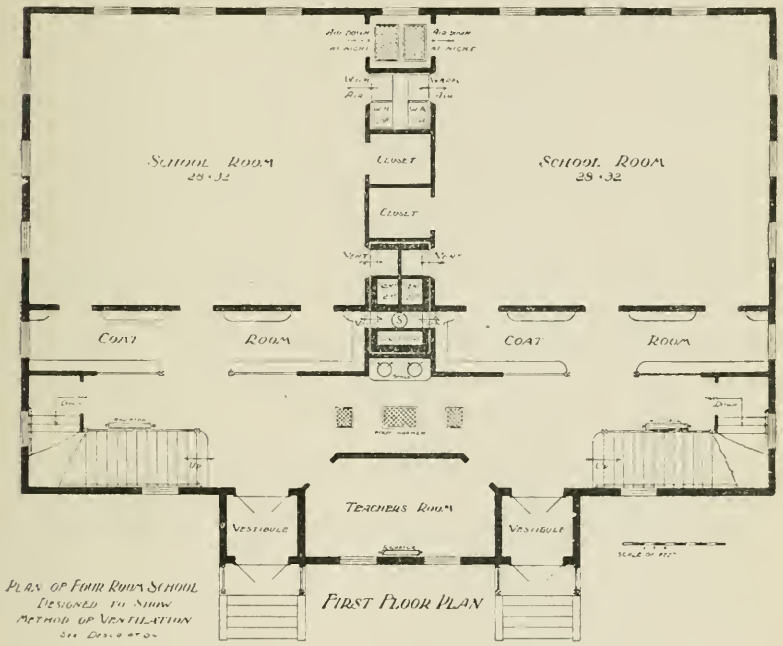
BASEMENT PLAN

be supplied either in the rooms or in the fresh air chambers in the basement. A four-horse power gas engine has been proved sufficient to give to a 4 ft. diameter fan enough revolutions to supply 1,000 persons (pupils) with 2,000 cubic feet per head per hour; hence with any system of steam heating, boilers of sufficient power can be economically used, even where electricity is obtainable for supplying power to the fan.

In the problem here we may assume that the outer air is to be heated to a temperature as low as 15° F. in the basement cold-air chamber, to be delivered in the room at 70° F., and that for colder weather steam coils be placed in the rooms for subsidiary heating.

In practice it may be said that the same number of heat units is required to raise water through any degree of temperature from 32° and 212° F., and proportionately air through any degree from

PLATE No 2



15° to 70° F., the ratio between air and water being at 212° F., as 1 to 1,000. Now the weight of a cubic foot of dry air at 32° F. and 30 inches of barometic pressure is 566.9 grains, or 1,000 cubic feet equal 81 lbs. Assuming that a cubic foot of water at 212° F. weighs 60 lbs., it will hold 10,800 units of heat. Hence it would raise 3,272 cubic feet of air through 55° F. It has been estimated that the combustion of 1 lb. of coal will produce 14,000 heat units, and if the combustion in an ordinary furnace amounts in loss to 3,200 units, or more than one-fifth, we find that 1 lb. of coal will raise

1 cubic foot of water from 32° to 212° F., or will heat 3,272 cubic feet of air. Or, roughly, 4 lbs. of coal will be sufficient to heat the 12,000 feet of air required to change the air of a room, 32 ft. x 25 x 15, in 7½ minutes. It is apparent that the amount required will be the same, whether the method of heating be by hot water, steam or hot-air furnace, provided the combustion be equally good in all and the loss of heat the same, if the mechanism provided supplies the heat to the fresh air all at the same rate.

Taking warm weather with cold weather throughout the winter season in Ontario, this calculation would mean that, for a school-building of 4 rooms of the above size and holding 200 pupils, from 25 to 30 tons of coal would supply an adequate amount of heat.

The illustration of principles thus given in some detail enables us in some degree to estimate the various factors entering into the problem of ventilation. Many simple methods are adopted for lessening the evils of over-crowding and air foulness in small buildings, but the scientific problem having had its practical solution in a large measure determined, it now requires some specific measures for its systematic application to schools and public buildings. As an allustration of modern systems in practical operation the following may may be given. It is from the Massachusetts report for 1896.

The plans are simply to show how the heating and ventilation of a four-roomed school building may be simply arranged:

The basement provides for the boiler-room with a 30 h.p. boiler, a cold-air room, the coal-room, the boys' and girls' playrooms, the w.c. and lavatories.

The ground floor has its hall-ways, and 1st and 2nd schoolrooms, its inlets and outlets for fresh air, and its cloakrooms.

The first floor has the principal's room, and the 3rd and 4th rooms, similarly heated and ventilated.

The third plan shows us in section the ducts and arrangements of cold-air room, and valves for regulating the temperature in the rooms, operated either by a chain or thermostat.

The areas of the ducts are given, while the heating provides for steam coils in three series so that 100, 120, 140, square feet of radiating surface for each room, may successively be turned on as the

external cold increases. In some the heating and ventilating arrangements provide for part of the steam coils to be in the school-room, and these supply the extra heat in severe weather by direct radiation. The ventilation may similarly, and with advantage, be supplied by a fan. One of 3 ft. diam. not exceeding 600 revolutions per minute will supply more than the calculated requirements of such a building.

It is apparent that with whatever system we may adopt there are many details in its practical operation which demand intelligent supervision if successful results are to be obtained. The questions

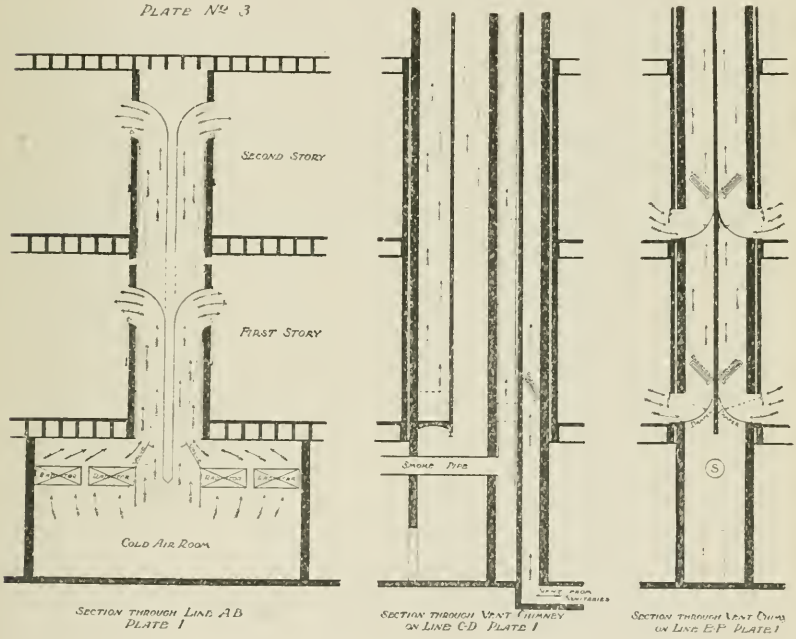


PLATE Nº 3
SECOND STORY
FIRST STORY
COLD AIR ROOM
SECTION THROUGH LINE AB PLATE I
SMOKE PIPE
SECTION THROUGH VENT CHIMNEY ON LINE CD PLATE I
SECTION THROUGH VENT FLUES ON LINE EF PLATE I

of friction and the size of fresh-air ventilating shafts, the velocity of cross-currents of air at the entrance of the shaft for fresh air from the exterior, the variations in barometric pressure and in external air temperature, all demand an intelligent comprehension of such causes and their effects, and of the means in the mechanism of ventilation of making compensation for such variations. From the standpoint of legislative enactments to provide for the application of scientific means to secure a standard of ventilation in any public building and

for supplying such system of expert officers for inspecting and regulating this work in public buildings in this Province, it would appear evident that at the present time there is no means similar to that for many years in operation in Massachusetts adequate for the work to be done. Local Boards of Health have, under the general provisions for inspection of the Public Health Act, probably enough powers to correct any serious unsanitary condition, but the exact scientific knowledge requiring to be applied to any particular case demands some special scheme to be formulated, so that new buildings in all urban municipalities and all school buildings in rural districts should have their plans approved before construction, and certainly proper provisions for ventilation, while definite powers to compel the adoption of adequate measures in old buildings should be put into systematic operation.

It will be, gentlemen, for you who are trained in the exact sciences which relate to this important matter, to so influence those in the position of municipal officers and trustees of schools to institute such improvements as will attain such desirable results as I have endeavoured to set forth.

NOTES ON THE DEVELOPMENT OF WATER POWER.

T. Barber, Grad. S. P. S.

As little or no attention has been given to the subject of water power by those who have addressed your Society in past years, and as the engineering profession generally devotes so little of its time to this most important subject, a few remarks to your members might produce a healthy and desirable examination of the subject.

It is not my intention to go closely into the details of the subject, but to give such general ideas as may be useful to all classes of the profession; to impress on all the great economic importance of it; to follow out quickly the development as it has occurred and to form a basis of thought on which a more intimate and thorough knowledge of the principles governing it may be built.

While the natural and economical course would have been to develop to their full capacity the abundant supply of water powers around us, we have allowed this most fruitful and inexhaustive source of energy, furnished us directly and without process of ages by the sun, to vent its mighty forces on the rocks and stream beds. At the same time we have been denuding our forests and coal measures so that at last when our extravagances are apparent all around us, we have begun to look at the future with some apprehension.

So far as our heat, light and power go we need have little fear, for by the sun's mighty power and the law of gravitation, we have the three great sources of energy around us,—water falls, winds and tides. These will always be with us, for without them and their causes we could not live; their magnitude, were it possible at this early date to estimate it, would be found to satisfy the most extravagant demands of a universal civilization.

All three sources present unlimited scope for investigation and invention, but we are to confine our attention to the subject of water

falls which, without presumption, may be said to be the most important of the three. Wind and tide are intermittent, but water flows on forever.

As with our forest and mineral wealth, we may squander the energies of our water falls, and it is only by devoting ourselves to the economical features of the subject that we may hope to see them equal to all the demands made upon them.

Let us think right here what a field of usefulness electricity has opened up for them. Without it we might well entertain apprehensions for our future light and heat, and even for power itself. What a congestion it would be to have all the manufacturing concerns of the world gathered around the water powers within the limits of gearing.

All statements in this subject need qualifying, and hence the difficulty in clearly and honestly enunciating it. I have intimated that almost all the energies of our water falls have been allowed to waste themselves, but, of course, a large proportion of the convenient ones have been utilized; the remainder were waiting, as it were, for the advent of electricity.

Water as a motive power has long been used to serve man's purposes. Next to the muscular and animate forces of nature it was the first to bow to his ingenuity.

Its constraint to produce useful and economical results is based on a few simple propositions which reveal themselves on a little practical and theoretical investigation: it requires no complicated machinery, and is the cheapest and most direct and satisfactory source of energy at our command.

If this statement be true one would, on the surface of things, wonder why improvement has come so slowly. Water powers, however, have their disadvantages, and when we remember that the steam engine was introduced at a time when scientific and mechanical skill would most likely have been brought to bear on the subject, and that the steam engine overcame the most serious objections to the water wheel, we have the explanation at once.

Had electricity superseded the steam engine it is hardly possible to estimate what the conditions would have been to-day. Electricity also overcomes many of the difficulties and objections which a bare

water power presents, besides it overcomes many of the main objections to steam engines themselves. There is no more self-contained and economical device due to man's ingenuity in constraining natural forces than an electric car, propelled, heated and lighted by electricity generated at a water fall.

Neglecting what might have been, let us apply ourselves to what has occurred.

Naturally enough the first method of utilizing water power to present itself was that of pure gravitation. This was accomplished in the overshot water wheel, which received its water at the top of the fall and carried it down to the discharge level in buckets on its periphery, similar to those used in the elevation of grain.

Here, as in all forms of water wheels, the improvements, though not complicated, came slowly. The air vent to insure promptness of discharge; the proper curving of the buckets to insure of the pressure being in the direction of motion as far as possible throughout; these and other details of improvement were in time worked out.

This primitive wheel under suitable conditions gave a very high percentage of useful effect and, strange to say, at its best is barely excelled in this respect by the most modern turbine. Its faults and inconveniences were many however, and it has had to give way to other and more suitable forms. In the first place, its size made it cumbrous, and for all but low heads necessitated ponderous gearing to give the proper speed. It would not stand any back water in the discharge race and, worst of all, became fearfully encumbered with ice in the cold weather.

Here in Ontario we have not seen one of these overshot water wheels for many years, but in the lower provinces of Canada a few are extant. I know of one driving a planing mill in Nova Scotia, but it is to be replaced this summer by a modern turbine water wheel, principally on account of the ice difficulty.

In the next form of water wheel attempted, gravitation was still the principle involved. The breast wheel was an attempt to improve on the method of applying the water. It was thought that by receiving the water lower down and by confining it in a sluice around the buckets from the point of reception to the point of discharge, better results would be obtained. There were many good points about it

but its faults were numerous, its principal one being its increased size over the already gigantic overshot wheel, and this insured its early disuse.

The next principle to be attacked was that of impulse, or the direct application of an issue of water to the runner. The undershot water wheel was the result and may be styled the primitive impulse wheel.

This wheel had quite an extensive application in the early American saw mills and was known here as the Flutter wheel. Its efficiency however was low and it finally resolved itself into a current wheel, an occasional one of which may still be seen where dams do not exist.

With the old wooden constructions, impulse wheels were easily racked and with the little freedom which wood gave for proper lines and curves, their economical results were very poor; it is only under the most favorable circumstances and with modern forms and materials that they have been brought to a high state of efficiency. They will not answer all purposes, but have particular advantages under high heads and will be spoken of again in that capacity.

In our treatment of the subject we are now past the "Wooden Age," and with it passed the idea of pure gravitation. It is therefore time to state the basic proposition as it presented itself at this date: "How can the momentum of an issue of water best be arrested and communicated to the runner of a water wheel?" This is the problem to-day: it has not changed during the long and progressive century. In its solution the turbine principle is predominant, and for the majority of our situations we have the turbine water wheel as opposed to the old plain water wheel or simple runner.

Let us now proceed to see how the proposition has been attacked.

In the early part of the century the principles of reaction presented themselves for investigation, and a number of turbines on this principle were introduced. Reaction consists in relieving an issue of water under pressure, in the opposite direction to that in which motion is required to take place.

Dr. Barker's mill was the first and simplest attempt at utilizing the principle of direct relief; Whitelaw's "Scotch Turbine" followed and was the only purely reaction turbine of the direct relief type to

contribute to the economics of water powers. There were no means of regulating the supply of power from a given wheel without destroying most of that in excess of the requirements, and this defect was not long in proving fatal to this particular form of wheel. To-day, this original form of reaction wheel has left the arena of turbines and may be seen watering our lawns and sprinkling the vegetables in a greengrocer's window.

By Newton's third law we would be obliged to think of all turbines as reaction wheels; but we have restricted the term to a definite principle, and hence its use here is not ambiguous.

The principle of pure reaction has never been thoroughly satisfactory and except for special purposes and reasons is seldom met with alone in the construction of modern turbines by men of ability. However, ninety-five per cent. of modern turbines work by a combination of impulse and reaction, in which reaction has the leading part.

While pure impulse water wheels in their initial forms were less satisfactory than the early reaction turbine, yet when the turbine principle was applied to them, they immediately established themselves in the economics of the subject, and are there to-day in their original as well as their modified turbine form.

In 1834 M. Fourneyron perfected his turbine. It is a pure impulse wheel; receives its water from the inside, whence it is projected by means of stationary guides onto the moving vanes or floats, at right angles to them at the point of issue. These moving vanes have their heel carried well around so as to remove the final momentum of the water as it leaves the outer rim, thus savoring a little of our principle of reaction.

This wheel gave a high percentage of useful effect, but was rather cumbrous and very expensive, so for general purposes of small heads or falls it cannot be said to have been a success. Its day had not come, and it is to later genius and economy in the subject that it owes its usefulness at the present day.

Let us pass on for the present. The attempts now were all to simplify the Fourneyron turbine, which was recognized as embodying the proper principles of utilizing the water.

It was attempted first by directing the water from the outside and discharging it centrally. This gave fairly satisfactory results, but lost whatever value there is in the outward tendency of the water in revolving and also increased the friction of the vanes. You may see this principle at work to-day in the upper half of the James Leffell turbine.

There was only one step needed to success, but it was nearly thirty years in coming in its true form. Instead of forcing the water to discharge into a contracted centre it was allowed to pass downward onto an inclined heel bucket which spread the discharge issue fully to the outside, and was curved and inclined in such a way as to arrest the highest possible percentage of the momentum of the water.

This is the principle of all the modern turbines of class number one, as we will style them, and they are the ones which comprise over ninety-five per cent of those in use. While details of this principle are still being considered and attempts made to bring them, if possible, to a higher state of perfection, there is no searching for other principles as pertaining to water turbines. I may say here that so far, most American inventors have neglected the real channel to success. In designing gearing they are very careful to find the proper curves which will work most harmoniously together. There are mathematical problems easy of solution which give the same information about water rolling on metal vanes.

Before leaving the subject of the design of runners it will be of interest to note why the early forms of water wheels and turbines were so largely an economical failure. With the single exception of the overshot water wheel, they endeavored to remove too suddenly the momentum of the water. Like starting a mass into motion, removing the motion takes time, and it was by adopting principles which gave this required time that true success came. The combination of impulse and reaction as outlined above accomplished the needed result and a high efficiency was obtained.

We shall see a little later, however, how pure impulse has been brought to recognize this principle and is to-day a grand success, and furnishes the most desirable forms for the most interesting and valuable of our water powers. It is also a problem at the present

time to develop what may be styled pure reaction to the same independent and economical state, but without the success which has crowned the other form.

The details in connection with this last statement are of interest to us all. It alludes to the attempt on the part of inventors and manufacturers to develop great power and speed on a nominally small diameter.

The word "nominally," must not be overlooked. With these wheels the diameter is given as that of the upper, or, when used as such, the impulse half of the wheel. The discharges however spread out far beyond this upper structure and relieve the issue fully to their outside, thus constituting the real diameter of the runner. It is the amount of water which the turbine is able to discharge which fixes its size and the larger the diameter of discharge the greater the volume that may be passed through; therefore when determining the diameter of a turbine, measure its runner across the outside of its discharge issues; this is unquestionably the true diameter and any other measurement is a deception.

While there is no real justification in practising this deception as to size, there is an idea and one worth looking into in introducing the water on a small diameter and spreading it to wider discharge issues. By introducing the water in the slower moving centre and spreading it in the discharge, it is possible to get a higher speed under a given head of water and also a fairly high percentage of useful effect. The power, however, corresponds to that of a wheel of the discharge diameter, as it should, since this is the true diameter, but is not greater for the amount of water used than that of other turbines of good design of the same size.

Also in attaining the result mentioned, other and more important features are sacrificed. Notably among them are the self governing properties of a nicely balanced combined impulse and reaction turbine: also it gives a runner which cannot be lifted straight out of its case, and those who have handled turbines will know what a serious disadvantage this is. These and other faults stamp the latest idea as far from being a great success. Apart from the proper form of the runner, there is the most important feature of the direction and regulation of water. Where impulse is made use of, and it should always be a factor, direction is of vital importance.

Assuming the revolving vanes to have their proper proportions, curves and angles, the water should meet them at right angles at the point of issue. There is a multiple of forms of gate rigs or entrance guides, some of which are well principled, others not. To get some good points it is unfortunate that in most rigs other good points must be sacrificed. I may say that there are two general forms which present the best features: the pivoted gate and the lifting cylinder. With the general ideas given, you will be able to realize for yourselves the points of advantage of the different forms. Learn to study the graphical part of a turbine catalogue; it will not be so apt to deceive you as other parts.

We have mentioned catalogues, and it suggests a few pointers well to have; for the present, however, we must pass on to the subject of regulation as it is so closely allied to direction. Most forms of gateage now in use accomplish regulation with very little loss of efficiency. So long as the stream lines are not too badly disturbed or the solid column of water broken and sprayed, with a good runner, good results will be obtained. However, turbines need not, and should not, be run down to a very low percentage of their maximum capacity; the design should be such that the range required would not be more than from one-half to full gate or one-third to full gate at most.

Apart from the features of direction and regulation, the most important considerations are those of simplicity and durability. Simplicity is desirable for many prominent reasons, the chief among which are durability and ease of repair. Owing to the many destructive agencies at work on a turbine, there should be few moving parts and these moving parts should be protected from rapid wear by the use of metals in their construction which give the longest service or wear under the action of river water. What I think would represent a simple wheel would be one with few and protected wearing parts, and one that could be renewed from one end to the other without destroying the original set or disturbing the base. Also in this connection it will be well to mention that the runner must absolutely be of one single piece. All attempts at bolting its parts together have after a little usage failed, and even cast part have given trouble, so great is the racking effect on them. I will not go farther with you into the details of turbines, but let us now look at our ability

to meet the requirements of to-day. While our water falls are of all heights we may say, their requirements are practically met by three classes of turbines. These we have at our hand and all are in a high state of perfection.

Taking as our first class the falls up to sixty feet in height: in this number we include a very large proportion of those which exist or are made; their aggregate power may not, however, bear so favorable a contrast. For these falls the latest or combined central and downward discharge turbines answer all requirements. It is no wonder then that this form of turbine has been so largely exploited and exists to-day in such great variety. We have just finished a glance at their details and so need not dwell here.

Our second class will include the falls between sixty and possibly three hundred feet in height, and we will stipulate that the volume of water is large; under these conditions nothing is known to excel the original Fourneyron turbine. The absence of reaction removes the excessive downward or axial pressure which in wheels for lower heads is borne on the footstep; also, the pressure of the water inside the runner may be used to suspend the immense weight of shafting and connections which metal, lignum or other bearings would be unable to stand except by their extravagant use and a consequent great waste of power and lubricants.

The honor of utilizing high falls of great volume belongs to Switzerland, and it was from there that the ideas came which have begun the harnessing of our mighty Niagara.

Niagara is our greatest living example of this class of falls, and as most of us have been fortunate enough to see the development for ourselves, and as full descriptions appear from time to time in the engineering periodicals, further details here would be superfluous.

Where the quantity of water in this second class of falls is limited and where the height exceeds the rough limit set, a third class of turbines is required.

This class may be considered more as motors than otherwise, and, without prejudice, may be said to be most ably represented by the Pelton water wheel. It is a pure impulse wheel and receives its water from one or more nozzles around its periphery. It does not attempt to check the issue suddenly; its curves are well proportioned

and principled, and its percentage of useful effect consequently quite high.

We have now discussed quite widely the various forms of turbines and their application to different situations. A few general remarks may be in point and, finally, some hints about installing them may form a useful conclusion.

To begin with, let me finish with the turbine catalogue. I have said to study the graphical part as most important and reliable: the only other point which we will consider will be the tables of power, speed and quantity of water. In very few instances are these reliable to the extent they should be. I do not want to create uncertainties, but unless a manufacturer is prepared to guarantee that under favorable conditions of installation and connection his turbine will work fully up to the tables, it is well to allow a good margin of power and quantity of water. In any case there is no harm in having an excess of power for emergencies such as backwater or overload. There seems to be some doubt as to the speed as given in tables. The speed given is of course that which will obtain at full load; when running light, the speed will probably be ten or fifteen per cent. higher.

Another point of interest is the fact that the theoretical and practical nomenclatures are exactly opposite. In practice a horizontal wheel is one having its axis horizontal and its plane of motion vertical, while in all literature on the subject of hydraulics, such a wheel is designated as vertical. So with the vertical wheel: in practice the position of the axis designates the wheel, while in theory, the plane of motion is the naming feature.

While this is well to know to save misunderstandings arising, a more important point is that of efficiency.

Were we to observe all known precautions in placing our best turbines and in removing obstructions and rough frictional surfaces, probably eighty-five per cent. of useful effect would be a common attainment. Under conditions as they exist, from seventy to eighty per cent. is the usual result and may be looked on as fairly satisfactory.

Tests of efficiency are usually conducted under the most favorable circumstances and conditions to the turbine in point and perhaps a high efficiency might be recorded for one, which in actual practice where a wide range of conditions are to be met, would be

entirely useless. In this connection it will be well to remark that though in this subject testimonials are usually reliable so far as they individually go, still, to prove a good case for a certain turbine by means of them, they should cover a wide range of conditions. Of course the idea of special wheels for special cases is quite admissable, but one should be sure that their special features really do exist and that they meet well the special conditions of the case; often, the speciality is most prominent in the price.

There being two materials in general use in the construction of penstocks and connections, it will be well to call up for consideration the advantages and disadvantages of each.

Both materials when good, answer well the purpose for which intended. At present iron is the more expensive material in most localities; apart from this its distinguishing fault is that of bridging internally with ice during the cold weather and then on a slight moderation of temperature, precipitating the whole mass onto the turbine, rendering it liable to break or to choke.

If there is one detail of installation of more importance than another it is the matter of giving the water plenty of room to reach and recede from the turbine. On account of their expense, the tendency with iron head races or flumes is to cramp the supply and cause it to flow too fast to the wheel. Examine tables of the spouting velocity of water and the resistance to flow in long pipes and you will understand the loss. For a practical basis a velocity of eight feet per second constitutes a loss of one foot of head at the issue and this loss varies directly as the square root of the velocity; to this must be added the resistance loss in long pipes. It is taken as good design to allow a velocity of one and one-half feet per second at full flow.

Remember particularly that cramping of the discharge race produces equally serious losses; let the water spread and flow quietly and deeply from the turbine.

In many ways as important a point is to thoroughly strain the water as it is about to reach the turbine. If all solid matter be removed there will be no breakages. Neglect to strain the water thoroughly and the cramping of the discharge pit and channel cause more annoyance, expense and failure than any other points. It is strange that the necessity for getting the water to the turbine should appear so much more important than that of taking it away.

Finally, see that your structure is of proper strength throughout and that it presents no weak points where the strains are greatest. Leaks, nowadays, are not permissible; water under pressure is too valuable. In this connection I may say, trust rather to bolts than to framed timbers; the advantages are apparent.

There are many other points of interest which I would like to mention, and besides it would be a pleasure to me to go farther into details and discuss the points mentioned directly and more fully with you. However, at this late date in your society's year it is impossible for me to meet you, and we must defer further discussion for a more convenient time.

You will grant me that this particular paper would have been much more interesting and effective were it possible to present cuts exemplifying all the principles and important points mentioned. Let me say, however, that you will find most of the ones in point in books on hydraulics and original forms in old treatises on mechanics, so that by reference you will get what unfortunately cannot be given here.

The subject is a broad and interesting one. It lends itself closely to the economics of our present and future existence here. Strangely, perhaps, the difficulties and complexities of steam engineering command more widely the attention of our engineers and geniuses. Of course, the original trouble of distribution and the possibilities of ocean navigation were great stimulants, besides the wider field for invention.

Yet, think of it in this light:—Ten to fifteen per cent. of useful effect from fuel—neglecting oils and gases—expensive and complex machinery to constrain its energies; excessive handling of materials to supply it; many attendants to regulate it.

With water power:—Eighty per cent. of useful effect; simple machinery to constrain its energies; no handling of materials; small attendance.

Should we not therefore devote ourselves to the careful and complete development of this most economical and satisfactory source of energy; especially so since we have electricity with which we can distribute its power.

Meaford, April 5th, 1900.

FIRE MAKING.

W. H. Ellis, M.A., M.B.

Whether or not there is any people so low in the scale of civilization as to be unacquainted with the method of lighting a fire, there is no doubt that among many savage tribes the task is a difficult one, and, consequently, great pains are taken to keep a small fire constantly smouldering, which may be used at any moment to kindle a larger one. Women were often entrusted with this task, and among some tribes a society existed whose members were devoted to the purpose of keeping up a perpetual fire. The origin of the order of Vestal Virgins, and of the perpetual altar fires of the ancients at once suggests itself.

Of the various known methods of producing fire, the burning glass, electricity and chemical action are, for obvious reasons, not employed by savages. The means used are friction, percussion and the compression of air.

An interesting instance of fire making by the compression of air is described by Mr. Stertchly (J. Anthrop. Inst. xix. 4, 456) in an article on the fire syringe of North Borneo. This syringe is cast of pewter. A similar implement made of buffalo horn is described by Mr. Worcester ("The Philippine Islands," p. 298) as being used by one of the wild tribes of North Luzon. "In the front face of the piston is a hollow which is filled with dry plant hairs of a peculiar sort. The operator inserts the head of the piston in the open end of the cylinder and a sharp blow drives it suddenly home, violently compressing the air, and generating heat enough to set the plant hairs on fire. The piston is instantly withdrawn, and the spark thus obtained is utilized to start a blaze. To perform this operation successfully requires long practice. I have yet to see a white man who professes to be able to do it, and how the natives first came to think of getting fire in such a way is, to me, a mystery."

Much more obvious is fire from the sparks made by striking stones against hard oxidizable substances such as flint and steel, or quartz and iron pyrites. In such cases the heat of the impact ignites fragments of the metal or of the sulphide which fall burning through the air as a shower of sparks upon a prepared combustible.

The use of friction between two pieces of wood was widely disseminated among savage races. It was employed throughout both North and South America, in Polynesia, Australia, Asia and Africa.

Fire by friction with two pieces of wood is produced in three ways, by ploughing, sawing and boring. (Walter Hough, American Anthropologist, III. 359, 1890.)

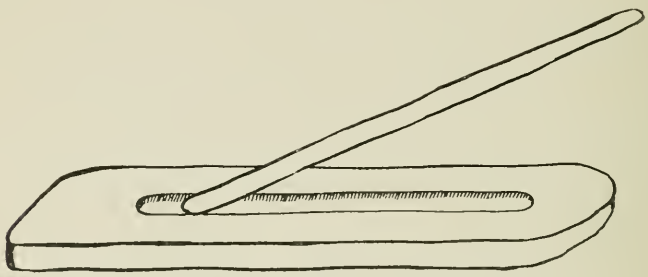


Fig. 1.

In the first method, which was used by Polynesians and some Australians, the pointed end of one stick is rubbed against another so as to produce a groove, at one end of which the borings produced by the operation are collected. Sufficient heat can be produced to set fire to these borings and from them a fire can be kindled. (Fig. 1.)

The second method (Fig. 2)is used by Malays and Burmese. Mr. Worcester (loc. cit) gives an interesting description of the use of this fire saw in the Philippines:

"I had always believed the operation of making fire by rubbing two sticks together to be a long and difficult process, requiring great strength and skill. In reality it is a very simple and easy matter, *if one has the right sort of sticks.* All that is necessary is one joint of thoroughly dried bamboo, say three-quarters of an inch in diameter. This is halved, and into the concave side of one of the pieces a V-shaped groove is cut, extending through to the outside, where it

opens by a long narrow slit. This half of the joint is now placed convex side up, on some smooth, hard surface. From the other half is fashioned a piece shaped somewhat like a paper-knife, and one of its edges is sharpened. This the fire-maker grips firmly in both hands, places it edge down on the convex surface of the other half-joint, and at right angles to the groove in it, and begins to rub slowly and steadily, bearing on hard. The sharp edges of the slit scrape wood dust from the upper piece, which, in turn, soon wears a groove into them, the dust falling down through the cleft. In from ten to fifteen seconds smoke begins to show faintly. In twenty or thirty more, as the rubbing grows rapidly faster and faster, it rises in little clouds. The operator suddenly stops, strikes the half-joint a sharp blow or two, to dislodge any sparks that may be clinging to

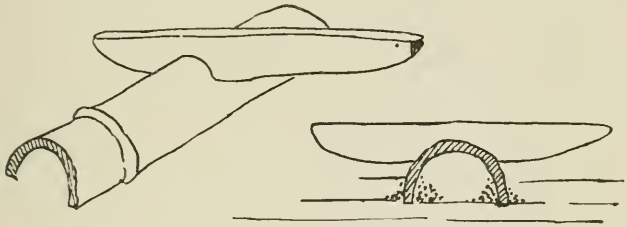


Fig. 2.

its under surface, and then snatches it up, exposing a little conical pile of charred wood-dust, at the apex of which glows a bright spark of living fire. Hastily pressing a handful of shavings down on this, he blows on them two or three times, and they burst into flame. The trick is simple enough when one once learns it. I succeeded in getting fire on my second attempt."

The third method (Fig. 3), that by boring, is much the commonest of the three. It is the method employed by the Iroquois and Algonquins of Canada, the Dacotahs of the Western plains, the Esquimaux and the Indians of South America, as well as many tribes in other quarters of the globe. The boring motion is produced either with the hands or by the help of some mechanical contrivance. The Indians of this continent were very expert in the use of this fire hand drill. According to Lafitan (Moeurs des Sauvages Americains, II., 242, quoted by Hough loc. cit), the Hurons and Iroquois

took a flat piece of cedar near the edge of which they bored a hole with a beaver tooth. From this cavity a little canal led to a match of frayed cedar bark. Inserting the pointed end of a round cedar stick in this hole they rotated it with their hands with such violence and rapidity that the borings which were pushed out by the canal took fire and ignited the cedar bark.

Captain Burke (Am. Anthropologist, III., 61) describes the Apaches as making fire in a precisely similar way by means of a fire stick which they carried attached to their lance staff by a string

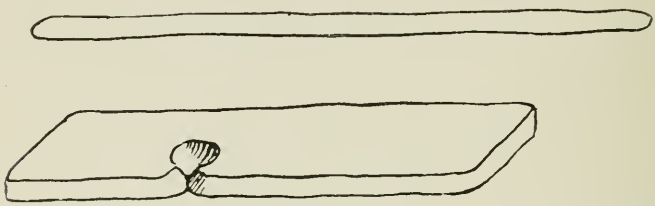


Fig. 3.

passed through a hole. He has seen fire thus made in from eight to forty-seven seconds. The Apaches told him that under the most favorable circumstances they could make fire by running their hands down the vertical stick once. This took two seconds. The introduction of lucifer matches is rapidly making this method of fire making a lost art among the Indians.

The production of fire by the rotation of a stick with the hands alone is a matter requiring great skill and knack. Much more so than either the fire plough or the fire saw.

Sometimes the rotation of the fire stick was produced by mechanical means. Thus among the Esquimaux one man pressed down the stick by holding a stone in which a hollow had been made in which the upper end of the drill revolved, while a second man rotated it with a thong twisted round it and held in both hands. Other Esquimaux used a bow, the string of which was twisted round the drill. With one hand they held the "hearth" stick, with the other

the bow, while the stone in which the drill revolved was held in the mouth. The Iroquois used a weighted drill rotated by a thong twisted round it like the string of a top.

By means of one of these mechanical fire drills it is quite easy to kindle a fire. The essential thing is the proper construction of the cavity close to the edge of the "hearth" with a canal to allow the heated borings to escape at one place and collect in a little heap. With a bow and drill of this kind, starting all cold, one can easily and certainly produce smoke in less than two seconds, and fire in a very short time.

TENSILE STRENGTH OF RIVETS AND BOLTS.

D. C. Tennant, Grad. S. P. S.

Some and possibly most of those who will read this article hold to the popular opinion that rivets in tension are quite unsafe, and that such a use of rivets is to be studiously avoided if not condemned. However, although this opinion has heretofore to a great extent governed shop practice, yet it must be acknowledged that in many cases the use of rivets in tension, while not absolutely necessary, greatly facilitates the arrangement of the detail. Fig. 1 represents a detail used to hang a loft from the box-girder of the floor-system above it. Fig. 2 shews the section of a bridge floor built for a prominent American railroad. Both of these figures were taken directly from actual shop drawings, and may be considered typical examples. It may also be stated that some designers have for the last twenty years utilized the tensile strength of rivets by riveting the floor beams to the under side of the bottom chord in many of their bridges, and it is reported that no failure has ever taken place in such constructions. The strength of knee-braces and diagonal braces sometimes depends on the resistance of rivets to tension stresses as well as to shearing stresses, but few if any object to such constructions. Owing to the above considerations and the lack of experimental data on the subject, the writer decided to make tests on the tensile strength of rivets and bolts.

There was a series of tests made at the Watertown Arsenal in the year 1896 on the shearing strength of riveted and bolted joints, and it will be well to note the results here as they give a very fair idea of the relation between the strengths of rivets and bolts in shear. The tests were made on $\frac{3}{4}$ inch and $\frac{5}{8}$ inch steel and iron rivets and bolts. All plates used were of steel. For every riveted joint there was a similar bolted joint tested; thus the tests were in pairs and

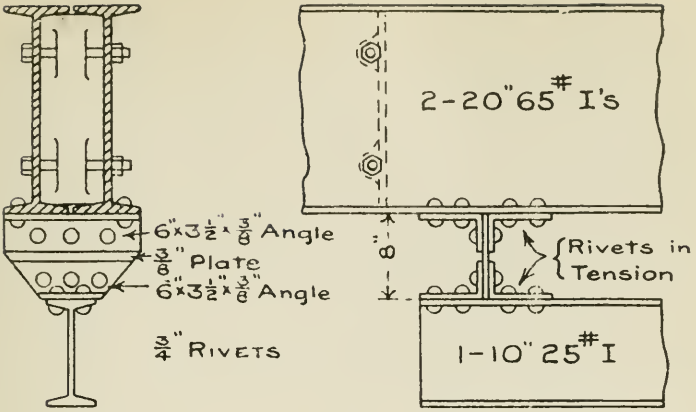

2-20" 65# I's
6"x3½"x⅜" Angle
⅜" Plate
6"x3½"x⅜" Angle
¾" Rivets
8"
Rivets in Tension
1-10" 25# I

FIG. 1

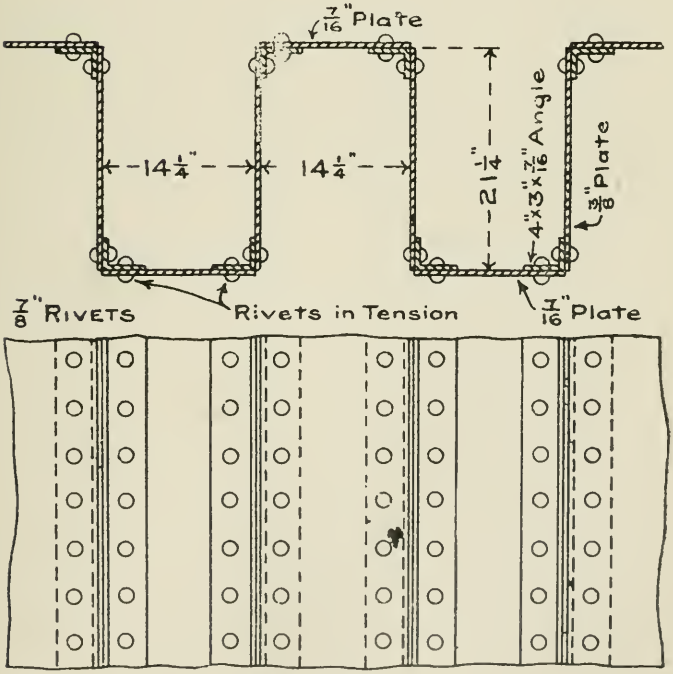

7/16" Plate
14¼"
14¼"
21¼"
4"x3"x7/16" Angle
⅜" Plate
⅞" Rivets
Rivets in Tension
7/16" Plate

FIG. 2

only those pairs of tests are shewn in Table 1 that resulted in the shearing both of rivets and bolts. On an examination of this table it appears that both rivets and bolts are slightly stronger in single than in double shear; that the number of rivets in a joint has very little to do with the strength per rivet, and the same holds true for bolts; that if we consider the rivets to completely fill the holes, the difference in shearing strength between rivets of different diameters is completely accounted for by the difference in the area of the cross-section of the rivets after driven; that rivets are stronger in shear per unit area of sheared section than bolts of the same nominal diameter, but that the greater the diameter the closer the strength of the bolts approaches that of the rivets. Steel in every case is stronger than iron. The American Architect and Building News for March 26th, 1898, discussing the above series of tests sums up as follows:—"These results seem to indicate clearly that the average strength of a bolted joint is only about two-thirds that of a riveted joint of the same sort, and that, if the diameter of the bolts or rivets is rather small in comparison with the thickness of the plates, the strength of the bolted joint may not be much more than one-half that of the riveted joint. It is therefore unquestionably advisable, in designing bolted joints, to provide at least one-half more bolts than the number of rivets given by the ordinary rules for riveted joints."

All of the following tests in connection with the tensile strength of rivets and bolts were made in the laboratories of the School of Practical Science. The tests were conducted under the supervision of Mr. J. A. Duff, to whom the writer is indebted for many valuable suggestions. The apparatus shewn in Figs. 3 and 4 was designed for the purpose and proved to be rigid and entirely satisfactory. The apparatus shewn in Fig. 3 tested one rivet at a time, the grip of the rivet being 1 inch; that shewn in Fig. 4 tested two rivets at a time, the grip of each being about $1\frac{1}{4}$ inches. With the latter apparatus, the load was equally divided between the two rivets and the maximum value was reached, and it had fallen considerably, before either of the rivets broke. On account of the lack of previous knowledge of the strength of both the rivets to be tested and of the apparatus used, it was thought best to make this series of tests on $\frac{3}{4}$ inch rivets. The Swansea Forging Company very kindly supplied all the rivets and bolts used in the tests. Rivets were made from

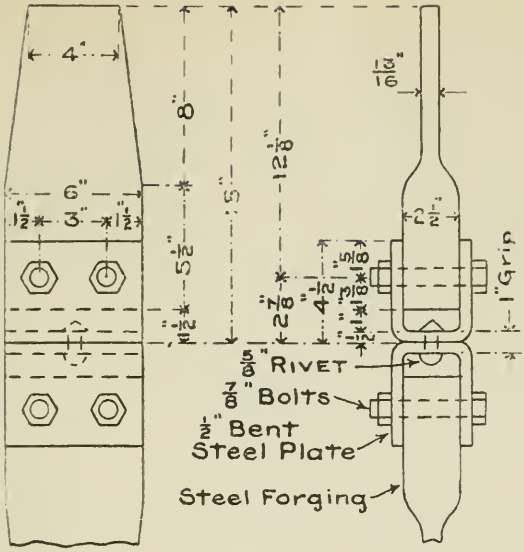

4"
8"
6"
1½"
3"
1½"
5½"
5"
12⅞"
2⅞"
4½"
2"
1"Grip
⅝" RIVET
⅞" Bolts
½" Bent
Steel Plate
Steel Forging

FIG. 3

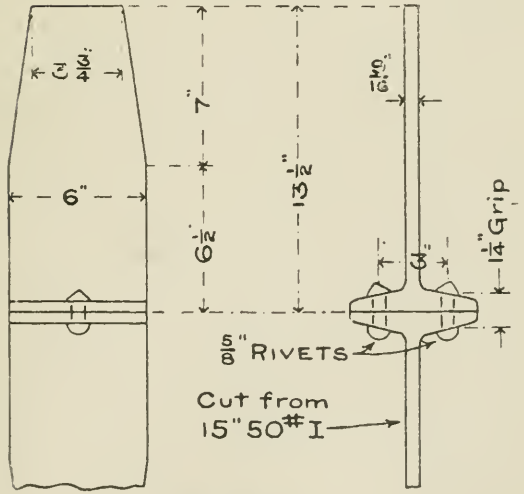

4¼"
7"
6"
6½"
13½"
6¼"
3"
1¼"Grip
⅝" RIVETS
Cut from
15" 50# I

FIG. 4

three bars of rivet steel and bolts from two. In each bar used there was left about six feet at the end for tests on the material, and the rivets and bolts from different bars were kept separate from each other. Each of the five bars used stood the nicking and bending test and shewed a fine silky texture. The riveting was done at the Polson Iron Works, Toronto, with a pneumatic hammer riveter, no special care being taken to obtain favorable results. In order to make it possible for a considerable number of rivets to be driven at one time, six pairs of bent plates were prepared to fit the steel forgings shewn in Fig. 3, and three pairs of I beams as shewn in Fig. 4, were cut out. The heads of the rivets which were formed in manufacture were button heads, while those formed in the driving of the rivets were cone-shaped, and as all the rivets were to be driven hot the holes were drilled $\frac{1}{16}$ inches in diameter.

Ordinary tension tests were made on the rivet steel, two test specimens being taken from the end of each of the five rods used, except No. 67, on which only one tension test was made. One specimen from each rod was used to determine Young's Modulus (E), extensometer readings being taken on the specimen for that purpose. The results shewn in Table 2 represent the average of the tension tests on each bar. The tests shewed Young's Modulus for the material to be about 28,000,000.

To perform the tensile tests on rivets the apparatus was gripped by the wedges of a Riehlé screw power testing machine and the rivets were thus pulled apart. The speed of the machine was uniform and the duration of each test was from six to ten minutes. The results of tests made with the apparatus shewn in Fig. 3 are given in Table 3, and with that shewn in Fig. 4, in Table 4. The first number in the test mark is the number of the bar from which the rivets were taken. With one rivet the parts of the joint were just separated when a load of 10,000 pounds was reached, and with two rivets at about 28,000 pounds. The most important dimensions of the rivets and their general manner of failure are given in Fig. 5. All the rivets tested failed near the middle of the shank except five, in one the cone head was very eccentric and it failed by the shearing off of the rim of the head, four others snapped straight across directly under the head with a coarsely crystalline fracture. All those which failed by ordinary tension in the shank stretched considerably as shewn in

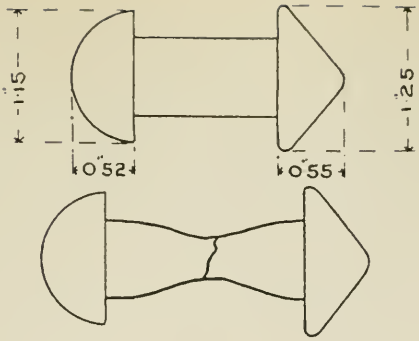


FIG. 5

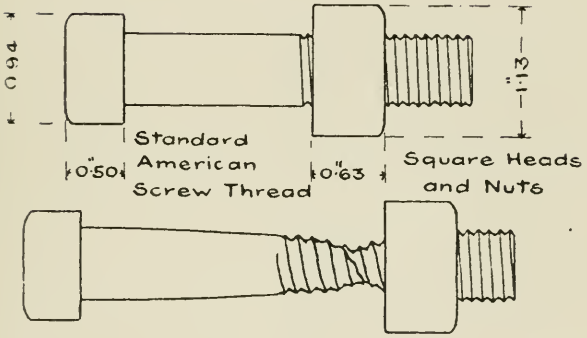


FIG. 6

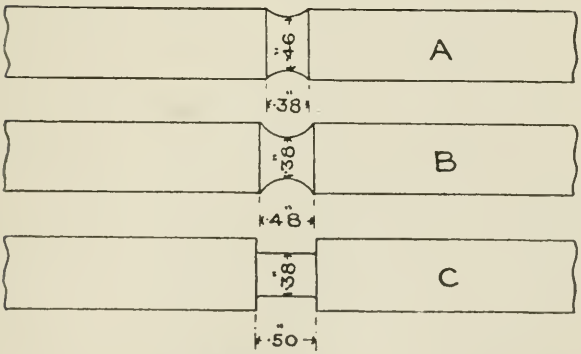


FIG. 7

Tables 3 and 4. It is very evident from the results of the tests that coarse crystallization introduces a great element of uncertainty in the strength of the rivet, and as this is probably caused by burning, great care should be taken in heating the rivets. It is also worthy of note that if care be taken in heating and driving, a tensile test is very much more likely to cause a failure in the shank of the rivet than in the head.

The results of the tests on the tensile strength of ⅝ inch bolts are given in Table 5. The dimensions of the bolt and a common appearance after failure are given in Fig. 6. Nearly all of the tests were made on two bolts at a time by means of the apparatus shewn in Fig. 4, thin bevelled washers being placed under the head and nut. As a check two tests were made with the other apparatus. To ensure the end of the bolt clearing the steel forging a number of washers had to be inserted between the bent plates, and this gave in the two tests on single bolts a longer distance between the head and the nut of the bolt, and part of the threaded portion of the bolt was therefore included in this distance. This probably is the reason that the strength in the two single tests is comparatively low. In these two tests the parts of the joint were just separated at a load of about 5,000 pounds, and in all the other bolt tests at about 9,000 pounds.

The excess in strength per square inch in the rivets as compared with the plain bar having been observed, it was thought that the action of the rivet might be similar to that of a grooved specimen, and tests were therefore made to determine if such was the case. Three grooved specimens, one like each of the sketches in Fig. 7, were turned from each of the five bars. The average elongation of the grooved portion was, for "A" 56 per cent., for "B" 38 per cent., for "C" 62 per cent. The average contraction in area was, for "A" 68 per cent., for "B" 69 per cent., for "C" 74 per cent. The grooved specimens "A" were the only ones in which the ungrooved portion was stressed beyond the yield point.

The ultimate stresses per square inch obtained from all the tests made in connection with this paper are given in Table 6. The stresses in the grooved specimens are calculated from the smallest area of the grooved portion, those in the rivets are calculated on the area of the hole, and those in the bolts on the area of the unthreaded portion of the bolt. It will be seen that the increased

strength of the rivets may be explained by considering them to act like grooved specimens "A" or "B." This would also explain why the bolts though threaded are as strong as the original bar.

In conclusion it may be said that outside of tensile strength the tension test of a rivet tells more about its quality than the shearing test since the tensile strength depends on both the shank and the head very directly. It is to be regretted that time has not permitted tests to be made on rivets of different diameters and of various lengths between the heads for the length between the heads very probably has a considerable influence upon the tensile strength.

TABLE I.

SHEARING STRENGTH OF RIVETS AND BOLTS.

(Compiled from Tests made at the Watertown Arsenal.)

No. of Rivets or Bolts in Joint.	Diameter. Ins.	Shearing Strength Of Rivet Pds.	Shearing Strength Of Bolt Pds.	Material.	Remarks.
2	3-4	24,250	18,840	Steel	Single shear
3	"	26,650	19,370	"	" "
4	"	25,020	19,220	"	" "
3	"	23,220	18,800	"	Double shear
2	"	23,260	16,600	Iron	Single shear
3	"	21,870	16,280	"	" "
4	"	22,850	18,130	"	" "
2	"	22,550	13,570	"	Double shear
3	"	21,520	13,080	"	" "
4	"	21,180	14,270	"	" "
6	5-8	16,000	8,630	"	Single shear
6	"	17,650	11,120	"	" "
8	"	17,350	10,890	"	" "
10	"	16,970	10,520	"	" "
12	"	14,160	9,420	"	" "
8	"	15,450	10,030	"	Double shear
8	"	16,360	9,010	"	" "
10	"	14,640	8,960	"	" "
10	"	15,400	9,490	"	" "
Averages	3-4	25,310	19,140	Steel	Single shear
	"	23,220	18,800	"	Double shear
	"	22,660	17,000	Iron	Single shear
	"	21,750	13,640	"	Double shear
	5-8	16,430	10,120	"	Single shear
	"	15,460	9,370	"	Double shear
	3-4	24,260	18,970	Steel	
	"	22,200	15,320	Iron	
	5-8	15,940	9,740	"	

TABLE II.

Tension Tests on the Material.

Bar.	Diameter ins.	Area sq. ins.	Yield Point pds.	Ultimate Strength pds.	Stretched Length		Contracted Area at fractur sq. ins.
					of 8 ins.	of inch of fracture.	
63	0.622	0.304	9,700	14,050	10.56	1.73	0.066
64	0.625	0.307	9,950	14,200	10.58	1.73	0.067
65	0.620	0.302	9,700	14,050	10.78	1.74	0.070
66	0.621	0.303	9,450	14,200	10.77	1.73	0.070
67	0.620	0.302	10,500	14,400	10.71	1.71	0.078

TABLE III.

Tension Tests on Rivets.

Test Mark.	Ultimate Load.	Length Between Heads Before Test.	Stretched Length Between Heads.	Area of Rivet Hole.	Contracted Area of Fracture.	Remarks.
	Pds.	Ins.	Ins.	Sq. Ins.	Sq. Ins.	
63-1	24,410	1.00	1.52	0.371	0.107	
63-4	22,770	"	1.46	"	0.135	
63-5	20,720	"	1.53	"	0.116	
63-6	22,000	"	1.43	"	0.122	
63-7	21,200	"	1.55	"	0.132	
63-8	22,300	"	1.56	"	0.096	
63-9	21,400	"	1.43	"	0.107	
64-1	22,400	"	1.60	"	0.105	
64-2	22,000	"	1.54	"	0.105	
64-3	22,100	"	1.50	"	0.110	
64-4	22,300	"	1.55	"	0.105	
64-5	22,800	"	1.48	"	0.119	
64-6	22,400	"	1.69	"	0.102	Joint slightly loose before test.
65-1	22,200	"	1.60	"	0.108	
65-2	22,560	"	1.48	"	0.119	
65-3	22,200	"	1.50	"	0.145	
65-4	21,850	"	1.45	"	0.139	
65-5	20,600	"	1.50	"	0.129	
65-6	21,600	"	1.49	"	0.119	

TABLE IV.

Tension Tests on Rivets.

Test Mark.	Ultimate Load.	Ultimate Load per Rivet.	Average Length Bet. Heads before Test.	Average Stretched Length Bet. Heads.	Area of Rivet Hole.	Average Contracted Area of Fracture.	Remarks.
	Pds.	Pds.	Ins.	Ins.	Sq. In.	Sq. In.	
63-2	46,600	23,300	1.30	1.74	0.371		Cone Head sheared off, very
63-10	44,800	22,400	"	1.79	"	0.128	eccentric.
63-12	46,900	23,450	"	1.79	"	0.119	
64-7	43,100	21,550	"	1.86	"	0.110	
64-8	42,600	21,300	"	1.86	"	0.102	
64-9	42,500	21,250	"	1.83	"	0.105	
65-7	49,100	24,550	"		"		Button Head tore off, fracture partly crystalline.
65-8	36,000	18,000	"		"		Button Heads tore off simultaneously, fracture wholly crystalline.
65-9	45,900	22,950	"		"		One Core Head tore off, fracture wholly crystalline.

TABLE V.

Tension Tests on Bolts.

Bar.	Number of Bolts in Joint.	Length Bet. Head and Nut before Test Ins.	Ultimate Load Pds.	Ultimate Load per Bolt Pds.	Remarks.
66	1	$2\frac{1}{2}$	12,900	12,900	Stretched and torn in thread.
66	1	"	12,300	12,300	" "
66	2	$1\frac{5}{8}$	27,600	13,800	Stretched and stripped in thread.
66	2	"	27,600	13,800	" "
66	2	"	28,000	14,000	" "
66	2	"	26,800	13,400	" "
66	2	"	27,750	13,870	" "
67	2	"	29,200	14,600	Stretched and torn in thread.
67		"	28,800	14,400	" "
67		"	29,000	14,500	" "
67	2	"	28,250	14,120	Stretched and stripped in thread.
67	2	"	28,900	14,450	" "
67	2	"	28,300	14,150	" "

In these tests the contraction in area accompanying the elongation of the threaded portion of the bolt caused it to draw away from the nut and this was followed either by the pulling of the bolt through the nut or by the tearing of the bolt at the root of the thread (all bolts 3 inches long under the head, threaded $1\frac{1}{2}$ inches).

TABLE VI.

SUMMARY OF RESULTS.

NUMBER OF BAR.	ULTIMATE STRENGTH IN POUNDS PER SQUARE INCH.					
	PLAIN BAR.	Grooved Specimens. (on Net Cross Section).			Rivet. (on area of hole).	Bolt. (unthreaded part).
		A.	B.	C.		
63	46,200	58,400	58,000	48,900	60,300	.....
64	46,200	60,000	62,300	55,400	59,300	.....
65	46,500	58,100	58,000	50,700	58,800	.....
66	46,900	59,400	58,400	50,300	.....	45,400
67	47,700	61,100	66,600	54,800	.....	47,600
Average.	46,700	59,400	60,700	52,000	59,500	46,500

The tests on the rivets from bar No. 63 were made first, and were communicated to a number of engineers, experienced in the designing of structural iron, with a request that they contribute a discussion on the use of rivets in tension. Some of these gentlemen very kindly acceded to the request and their opinions are given below.

It is greatly to be regretted that there was not time to communicate the results of the complete series of tests for discussion before publication, but unavoidable delays in the completion of the experiments and the necessity for publishing on a fixed date made this impossible. But although the discussions were written before the tests were completed, the writer believes that they represent the opinions prevailing amongst structural engineers.

MR. T. H. ALISON.

The experimental results recently compiled by Mr. D. C. Tennant in the laboratory of the School of Practical Science on the strength of ¾-inch rivets in tension, and on that of a similar bar in direct tension, give interesting differences, due to some well-known causes; and if it be possible to obtain by experiment the extent of the individual causes, an important advance would be made in the science of rivets.

Although the compilations are of a scientific nature, yet their value would be increased if in addition they were tabulated, as may frequently be observed in most engineering laboratories, so as to permit the engineer to readily grasp the results and to make mental comparisons with former experiments. It might, therefore, be suggested that the ultimate and elastic limit stresses might be given in pounds per square inch, the actual stretch in a length of 8 inches, and the reduction in area stated in percentage of the original bar.

The marked increase of 58% of a rivet above a bar will reduce to about 30% when it is considered that the $\frac{1}{16}$ inch hole is completely filled with the metal of the rivet, and this in turn may be partly accounted for by the favorable process of tempering during the rapid decrease in temperature of the rivet. The mechanical treatment in upsetting the head will add its quota of strength, for it can be shown from the extensive experiments of noted scientists that a bar exceeding its elastic limit by stretching, hammering, or rolling, adds to the tension, but the tenacity and ductility are reduced. These results are clearly shown by the present experiments, for the elongation has reduced some 30%, and the reduction in area at the point of fracture is lessened some 10%.

Dupuy, a French scientist, contends that rivets, as bars, have permanent set and are subjected to tension above the elastic limit in the cooling process, also that the outside fibres appear to have a greater set than those nearer the centre.

Riveted work predominates in structural steel work, where the rivets perform the duty that the link does in the chain, and accordingly it is essential that this particular detail should be studied and designed to give the most efficient results in counteracting time, the elements and the class of loading. Structures may be generally classified into those carrying practically quiescent loads, such as office and mill buildings, and those sustaining movable or radically varying loads as bridges and coal pockets. The latter class of structures with rapidly decreasing, increasing or impact loading taxes the rivet the greater; and for this reason experiments made under the most favorable circumstances do not reasonably apply to practice, otherwise the diversity of opinion regarding friction of plates, tension in rivets, and the complete filling of holes with metal would be less frequently heard.

Rivets in tension are occasionally used to facilitate shop practice and field erection, but their duty is quite secondary. Wind loads are provided for in small buildings by triangular brackets that transmit their stresses to the main structure through rivets in tension, but the factors of safety are considerably increased. Up-to-date practice does not permit the designing of an important detail in this manner, and for this reason structures seldom suffer from this tearing off of rivet heads due to direct tension.

If sufficient metal is used to form the heads of rivets, the strength in the heads will greatly exceed that in the shank, but the rapidity of shop work, or the difficulty of access to the work in the field causes uncertainty as to the concentricness of the head. The frequent use of too long or too short a rivet has its objection in the set coming down on one side, causing an unequal distribution of the load, and when the rivet is strained a bending takes place across the junction of the head with the shank.

If rivets in tension were customary, the details would add much to the weight of the structure, since the angles or projections transferring stresses would be acted upon, and the bending would have the greatest effect in the root of the angle—the weakest portion—thus necessitating extra strength and weight.

Although rivets at the time of driving have considerable initial tension, yet it is contended that continual jarring by moving loads eventually loosens them. This would be sure to occur if the rivets were strained through the heads, and the uncertainty of the proportion of load carried by each rivet would be mere conjecture. In case the rivet heads are acted upon by the vertical and horizontal components of forces a combined stress in tension and bending would be the result, which would add to the tension of one set of outside fibres and would relieve the diametrically opposite to the same extent, which would reduce the factor of safety.

Cracks in the heads assist speedy corrosion which is very evident by the records of boiler explosions.

In the heating of rivets by the accustomed coke forges or by oil furnaces, the absorbing of sulphur causes a coarse grained, brittle and hard-working material, the effect of which is frequently seen in the ready snapping off of a head when occasion necessitates the knocking out of a rivet. The hard working quality retards the upsetting

in the field where rivets in tension are most likely to be used in connecting different members. This gives an opportunity for blue heat to set in, which is detrimental to the strength if further work is expended in finishing the head of the rivet.

The experiments at the School of Practical Science were most likely performed under favorable circumstances, such as adding the stress uniformly and slowly, and using hydraulic or pneumatic power to drive the rivets, and yet in one experiment the head snapped off although the metal in the head should have given greater resistance. In the field, then, the use of rivets, owing to the objections mentioned, is questionable, and when we consider the completed structure carrying its varying and impact loads thus causing uncertainty as to the results of rivets in tension, no engineer should permit of such design. If it should be found necessary, however, to put in an occasional secondary joint in tension it would be much better to use bolts, the material of which has been fully investigated.

MR. F. M. BOWMAN.

I have been quite interested in the tests made by Mr. Tennant on rivets in tension. I note that all the rivets were made from the same bar, but that the results of the tests varied almost twenty per cent. This, I believe, can be accounted for from the fact that after driving, some of the rivets may not completely fill the holes. Driving the rivets with hydraulic power would fill the hole better, assuming always that the rivet is quite hot. The difficulty, however, with the use of rivets in tension, is the uncertainty. If the rivet head does not close down tight on either side, or if it is, in any way, imperfectly formed, it is of little value in tension. Also, whatever value such a rivet has, would not come into play until the other rivets were highly strained.

The greatest difficulty, however, to my mind, is due to the fact that the internal tension along the length of any well-driven rivet must be considerable; the hotter the rivet and the better it is driven, the greater is this initial strain. This is due of course to the cooling and contracting of the rivet after driving. I have known rivets to crack off at the head and can assign no other cause for the occurrence.

Few authorities allow any value for rivets in tension, and the highest I have seen is one-third their shear value. I would not care

to use more than this, and at such a value some other construction can generally be adopted which would be more economical and more satisfactory. Bolts can be used, but I do not like them, particularly in a structure subject to vibration.

MR. W. J. FRANCIS.

The writer is honored in receiving an abstract from Mr. Tennant's paper on Tension of Rivets, and in compliance with a desire expressed for the same makes the following remarks:

The results obtained are interesting and may prove of great value. It would appear very desirable to have an accurate record of the temperature of the rivet before driving, the number of blows administered in driving, the temperature of the rivet at the last blow and the temperature of the plates, which would be nearly the same as the atmosphere. The term "ordinary shop practice" is not definite, and from the writer's observations he would not be surprised to find vastly varying results from "ordinary practice" in different shops. In cold weather—to take an extreme case—rivets may be so driven that the heads fly off; while, on the other hand, a loose rivet may be formed in such a way as to make almost an ideal tension specimen—a rod upset at both ends. Between these extremes is it not possible to get all sorts of results, and have poor rivets shew up better that others which might be passed as good?

It seems scarcely fair to compare the tension tests of so many rivets with only one test from the bar, but does not the conclusion arrived at only indicate that the working of the metal improves its tensile value. This is clearly shewn in wire-drawing.

As to the use of rivets in tension in practice, the writer would say that he would not be inclined to place much reliance on the even distribution of the load over the different rivets, owing to the fact that it is practically impossible to tell the initial tension on any driven rivet. This being so, such a design could scarcely be called good practice. In the case of a bolted joint for tension, the range of initial tension can be brought within much smaller limits by setting up all of the nuts in the same way. But it seems best to avoid such joints altogether if possible.

THE STRENGTH OF GLASS.

C. H. C. Wright, B.A.Sc.

The following experiments were performed in the laboratories of the School of Practical Science under the direction of Principal Galbraith:

One of the lower sashes was taken out of a western window of the assembly hall of the school (top floor) and its single light of glass loaded and broken as indicated below. The glass had been exposed to the action of the weather for the past ten (10) years, was well bedded, and the putty was quite sound and hard.

The sash was placed with its weather side up on a carefully prepared box 8 inches high laid horizontally. Sides 12 inches high fastened well together were placed on top of the sash and then paper scales divided into half inches were pasted on each side. Light graduated pointers with their cardboard bases were placed on the surface of the glass. The whole made an arrangement as indicated in the accompanying sketch.

Portland cement was then sifted very gently over the surface of the glass care being taken to keep it of uniform depth, for which purpose the graduated pointers and scales already mentioned answered admirably.

The glass measured 36 inches by 36.75 inches and a bag of cement (88 lbs. net) was sifted over its surface, then a barrel (347 lbs.) was gradually added, this was followed by a box of cement of 78 lbs., this by a second of 54.5 lbs., and finally a layer of bricks of 88.5 lbs. was added to the superimposed load. The failure occurred while a second lot of bricks were being weighed.

The deflection was approximately 7/16 inches under a load of 429 lbs.

After the experiment the cement was passed through a sieve, the pieces of glass were collected and weighed, and from their appearance the glass was what is known to the trade as 26 oz. It was certainly thicker than double diamond and not so heavy as 32 oz.

A sheet of double diamond was next placed in the sash but was not bedded nor puttied, and the load applied as before. This was followed by sheets of 16 oz. and 32 oz. weight respectively.

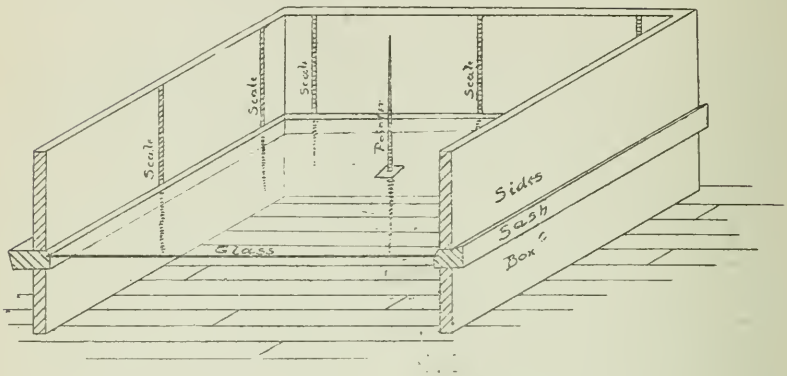
Old window, with glass probably 26 oz.

Size of glass—36 inches by 36.75 inches.

Weight of glass—15 lbs.

Failed under a uniformly distributed load of—656 + 15 = 671 lbs.

Pressure in pounds per square foot—74.55.



Double diamond.

Size of glass—36 inches by 36.75 inches.

Weight of glass—13.5 lbs.

Failed under a uniformly distributed load of 262 + 13.5 = 275.5 lbs.

N.B. This sheet of glass in its unstrained condition was badly warped.

16 oz. glass.

Size of glass—36 inches by 36.75 inches.

Weight of glass—10 lbs.

Failed under a uniformly distributed load of 322 + 10 = 332.

Pressure in pounds per square foot—37.

32 oz. glass.

Size of glass—36 inches by 36.75 inches.

Weight of glass—17 lbs.

Failed under a uniformly distributed load of 611.5 + 17 = 628.5 lbs.

Pressure in pounds per square foot—69.8.

INDEX TO THE FIRST THIRTEEN NUMBERS.

	VOL.	PAGE.
Allison, J. L. Transition Curves	ii.	52
Andrewes, E. Notes on the Geology of Rossland Ore Deposits	xiii.	128
Angus, R. W., B.A.Sc. The Gas Engine	x.	61
The Shaft Governor	xi.	76
Bain, J. W., B.A. Sc. Planimeters	ix.	19
Notes on Stamp Mill	x.	6
The Accuracy of the Assay of Pyritic Ores	xi.	67
Ball, E. F., A.M. Can. Soc. C.E. Asphalt Pavements	i.	40
Sewers	iii.	39
Water Supply	iv.	60
The Computation of Earthwork and Overhaul by Means of Diagrams	v.	48
Hydraulic Cements	v.	82
Sewage Filtration	vi.	44
Barber, T. Notes on the Development of Water Power	xiii.	189
Blackwood, A. E. President's Address	viii.	1
Description of the Finlayson Marine Pipe Boiler	viii.	189
Bowman, A. M. System of Survey in British Columbia	i.	19
Bowman, H. J., O.L.S. Municipal Engineering in Ontario	x.	177
Bryce, P. H., M.A., M.D. Underground Waters as Sources of Public Water Supplies in Ontario	iv.	15
The Chicago Canal and Some Sanitary Problems connected Therewith	ix.	55
Disposal of Sewerage	xi.	44
Land Drainage in its Sanitary Relations	xii.	119
Principles of Ventilation in their Application to Public Buildings	xiii.	174
Butler, M. J., C.E. Silica Portland Cement	xii.	100
Campbell, A. W., C.E. Roads and Streets in Ontario	x.	14
Road Construction	xi.	18
Pavements	xii.	106
Roadmaking	xiii.	167
Campbell, G. M. Vice-Work	viii.	33
Carter, W. E. H. President's Address	xii.	1
Chalmers, J. Double Track Tunnel Hamilton T. H. & B. Railway	ix.	61
Rat Portage Water Works	xii.	85

VOL. PAGE.

Chubbuck, L. B. Modern Systems of Interior Wiring .....xii. 58
Hydraulic and Electric Elevators .....xiii. 91
Chewett, J. H., C.E. The Removal and Destruction of Garbage .. ..vii. 11
Christie, Fred. W., C.E. Gold Mining in Nova Scotia.....xi. 129
Coleman, Prof. A. P., M.A., Ph.D. Mount Brown and the Sources of the Athabasca .....vii. 62
Connor, W. A., B.A. Solutions .....viii. 223
Corrigan, G. D. Modern Copper Smelting .....iv. 100
Davidson, J. L. Location and Construction of Crow's Nest Pass Railway .....xii. 135
Deacon, T. R. North Bay Water Works .....vi. 91
Dobie, J. S., Grad. S. P. S. The Action of Heat on Cement..ix. 126
Duff, J. A., B.A. Presidential Address .....iii. 82
The Fundamental Principles of Dynamics .....v. 27
Diagrams ....v. 61
The Country Roads of Ontario .....viii. 49
Tests on Tensile Strength of Steel Boiler Plate .....x. 184
Neely's Formula for the Strength of Wooden Beams..xii. 194
Elliott, H. P., B.A.Sc. Lightning Arresters .....ix. 13
A Discussion of the Considerations Affecting the Cost of Electric Power .....xi. 113
Ellis, W. H., M.A., M.B. Junker's Gas Calorimeter.....xii. 143
Fire Making .....xiii. 201
Galbraith, Prof. Technical Education .....v. 100
Goodwin, J. B., B.A.Sc. Tunnel at Niagara for Development of Power .....vi. 34
Niagara Falls Sewerage System .....x. 38
Gray, R. A. L. Power Switchboard and Dynamo Tending..viii. 201
Greenwood, H. F., C.E. Concrete on Trent Valley Canal....x. 80
Gurney, Cromwell. Illustrative Casualties in the Workshop..ix. 8
Haight, H. V. Gear Cutting .....viii. 178
Standards in Machine Shop Practice .....ix. 38
Air Compressors .....x. 123
Hare, W. A. The Process of Manufacturing Mechanical Wood Pulp .....xii. 12
The Problem of Speed Regulation in Plants Driven by Water Power .....xiii. 37

	VOL.	PAGE.
Harkness, A. H. Crushing Strength of White Pine	x.	180
Harvey, C. J. C.E. The Conjunction of the Nineteenth and Twentieth Centuries from an Engineering Standpoint	xii.	156
Haultain, H. E. T. Presidential Address	iii.	11
Extract from Letter from	iii.	109
Some Experiences with a Canadian Turbine in Austria	vi.	83
Hemphill, W. Construction of the Hamilton Cataract Power Company's Plant at DeCew Falls	xii.	76
Innes, W. L., C.E. Grading	viii.	5
A Brief History of Astronomy	ix.	26
James, D. D. Surveying in the City and Suburbs of Toronto	iii.	57
Johnson, S. M. The Maintenance of English Roads	viii.	17
Brickwork Masonry	ix.	153
Kennedy, J. H., C.E. Reference Points and Bench Marks	i.	27
Laing, A. T., B.A.Sc. The Waterworks System of Amherstburg and Essex	v.	55
Laing's Planetarium	ix.	138
Laschinger, E. J. Hirn's Analysis of Heat Distribution in the Cylinder of a Steam Engine	viii.	120
Lea, W. A. Photography	iv.	82
President's Address	vi.	1
Leask, W. Corrugations on Mill Rollers	iii.	63
Lott, A. E. A Re-Survey in Ontario	i.	24
Notes from an Engineer's Pocket Book	xii.	145
Ludgate, B. A. Problems from an Engineer's Pocket Book	xii.	145
MacDougall, A., C.E. Professional Prospects	vii.	7
McArce, J., O.L.S., D.T.S. The Crawford Gold Mine	vii.	26
McCulloch, A. L. Mortars and Cements	ii.	25
McDowell, R. Foundations	iv.	54
McFarlen, T. J. The Nickel Mining and Smelting Industry of Sudbury	vi.	48
McKinnon, H. L. The Cleaning and Annealing of Castings	viii.	132
McLennan, J. C., B.A. Roentgen Radiation	ix.	142
MacNabb, J. C., O.L.S. Proposed St. Clair and Erie Canal	vii.	62
McPherson, A. J., B.A.Sc. Specifications for Sidewalks	x.	20
Marani, C. J. Historical Review of Sanitary Science and the "Germ Theory."	iii.	20
The Separate System and the Brockville Sewers	iv.	36
Sanitary Plumbing	v.	7

	VOL.	PAGE.
Marani, V. G. A Short, Practical Essay on "The Sea and Its Waves."	v.	73
Merrill, E. B., B.A., B.A.Sc. Electric Traction as Applied to the Street Railway	vi.	57
Dynamo Design	viii.	205
Mickle, G. R. Freiberg Smelting Process	iv.	89
The Value of Undeveloped Mineral Claims	xii.	181
Minty, W. M., B.A.Sc. Notes on the Relation of the Mechanical Properties of Steel to the Chemical Composition	xi.	145
Mitchell, C. H., B.A.Sc. Earthworks on Roads and Railroads	v.	37
Triangulation Survey	vi.	23
Aerial Mechanical Flight	viii.	74
Monds, W. Circulation in Water Tube Boilers	xiii.	112
Morris, J. L., C.E. Masonry Foundations	iii.	52
Retracing Old Compass Lines	v.	70
Mundie, W. B., F.A.I.A. The High Building Problem	x.	28
Neelands, E. V. Some Adventures on the Abitibi	xii.	149
Mine Timbering	xiii.	137
Newman, W. The Drainage System in Essex and Kent	iv.	76
Palmer, R. K. Some Notes on Bridge Drafting	xiii.	119
Pedder, J. R., O.L.S. The Beeton Waterworks System	vii.	18
Raymer, A. R. Railway Surveys	ii.	34
Richardson, G. H. Rodding on Railway Work	ii.	9
Richards, E. The High Pressure Steam Boiler	xii.	9
Cold Storage	xiii.	76
Rosebrugh, T. R., B.A. Scale Calculus	iii.	48
Ross, D. A., B.A. Railroad Location in the Crow's Nest Pass Railway	xii.	29
Russell, S. Track Laying	iii.	73
Offsetts from Tangent on a 1° Curve	iii.	111
Notes on Railway Location and Construction in the North-West	iv.	42
Russell, W. Township Survey	iii.	98
Scott, A. M., '96 Arts. The Pendulum	ix.	81
Shanks, T. President's Address	xiii.	1
Shield's J. D. President's Address	vii.	11

	VOL.	PAGE.
Shillinglaw, W. H. Hot Water Heating	v.	20
Shipe, E. F. The Hardening and Tempering of Steel	viii.	169
Smith, C. B., Ma.E. Canadian Steam Railways	xiii.	158
Southworth, T. Forestry	xii.	114
Spiller, F. N., B.A.Sc. Asphalt and Asphalt Paving	vii.	44
The Use of Asphalt in Engineering Construction	viii.	150
The Modern Open-Hearth Process	xi.	5
Stern, E. W. Notes on Field Work of Railroad Construction	i.	9
Notes on Iron Bridge Building	ii.	44
Cable Railways	iii.	36
Stewart, L. B., D.T.S. Description of a Timber Limit Survey in the Rocky Mountains	iii.	68
Distance Measuring Micrometers	iii.	92
An Exploratory Trip Through the Rockies	vi.	96
A Canoe Trip on the Saskatchewan	vii.	74
A Single Form of Telemeter	ix.	148
Longitude by Lunar Distances	xi.	53
A Trip to the Yukon	xiii.	145
Stovel, H. R. Hints to Prospectors	xii.	177
Stull, W. W. History and Chemistry of the Cyanide Process	xi.	25
Tennant, D. C. Tensile Strength of Rivets and Bolts	xiii.	206
Thomson, R. W., B.A.Sc. President's Address	v.	1
Sewage Disposal in Ontario	viii.	194
Thomson, T. K., C.E., A.M. Can. Soc. C.E. Angle Blocks	ii.	50
Bridge Specifications	vi.	5
Notes on Cement	vii.	36
Foundations for a Twenty-one Story Building	x.	96
Thorold, F. W. Electrolysis	xii.	72
Tye, A. T. The Canadian Dawn Animal	viii.	138
Tye, W. F. Cross Sectioning	i.	31
Tyrrell, H. G. Explorations on the Battle River	ii.	20
Tyrrell, J. W., C.E. Hydraulic Mining in British Columbia	x.	88
On Snowshoes from the Barren Lands	x.	104
Van Buskirk, W. F., A.M., Can. Soc. C. E. The Ventilation of Sewers	viii.	128
Wagner, W. E. Aerial Cableways	xiii.	10
Withrow, W. J. Petroleum	ix.	38
Wright, C. H. C., B.A.Sc. Aspect and Prospect	ix.	134
The Strength of Glass	xiii.	221

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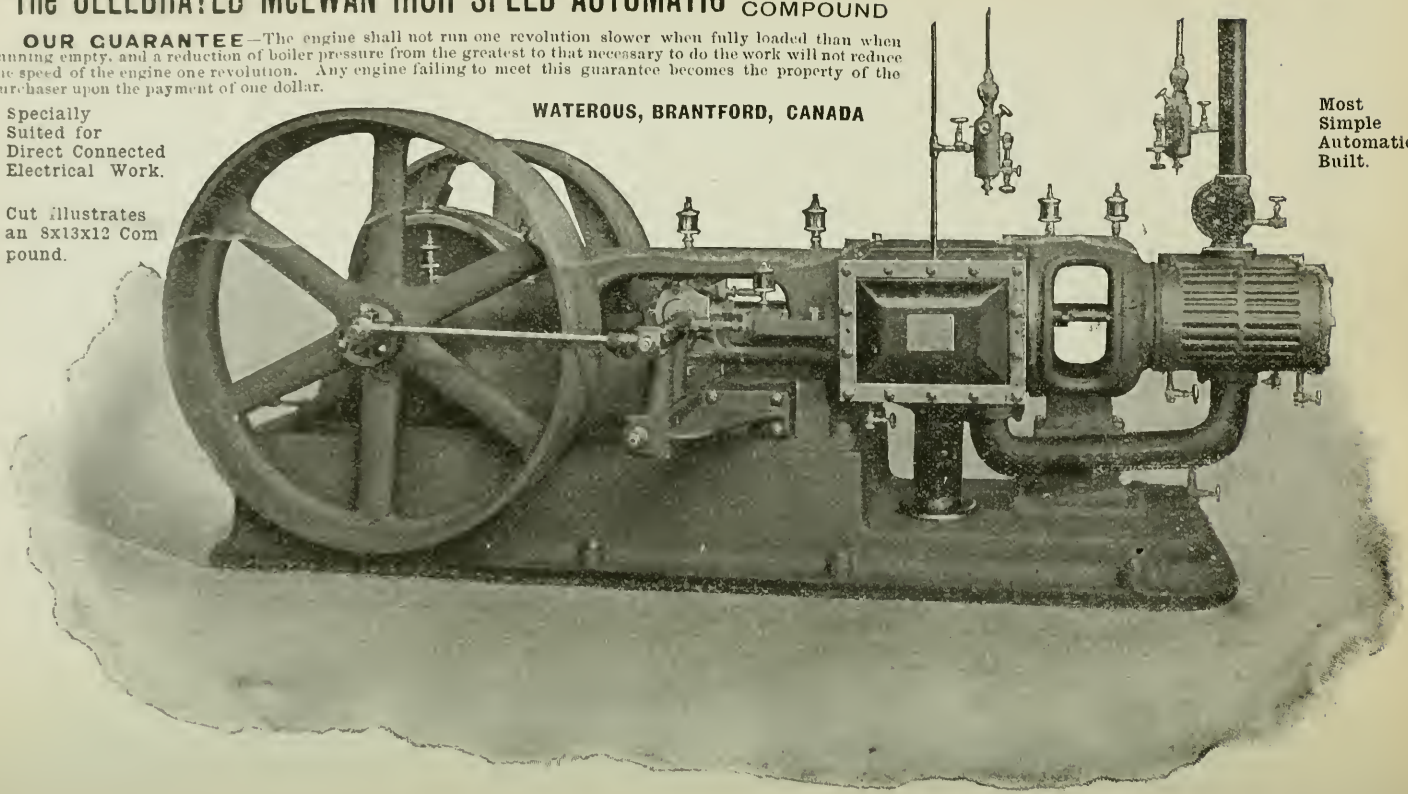

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Entered according to the Act of the Parliament of Canada, in the year one thousand nine hundred and one, by the Engineering Society of the School of Practical Science, in the Office of the Minister of Agriculture.

PREFACE.

The present volume consists of papers read before the Engineering Society of the School of Practical Science during the session 1900-1901.

As in the past, the papers all deal with some of the numerous branches of engineering. Besides being interesting reading, all contain valuable information and will, it is believed, be found useful not only by students, but also by graduates and others engaged in active professional life. The papers on Chemical Wood Pulp and The Conservation of Water for Power Purposes, mark a growing interest in those branches of engineering, upon which the development of this country largely depends.

The Society is to be congratulated upon having secured papers from Mr. H. G. Tyrrell, Mr. C. H. Mitchell, and Mr. A. W. Campbell, each a recognized authority on the subject of which he writes.

The thanks of the Society are due to all who have, by their contributions, or in any other way, materially aided its usefulness.

The present edition consists of 1,500 copies.

Toronto, April 17th, 1901.

CONTENTS.

		Page.
President's Address	F. W. Thorold, '00	1
Chemical Wood Pulp	J. A. Decew, '96	6
The Bonding of Broken Stone Roads	A. W. Campbell, C.E.	15
Exploring New Ontario	Alexander H. Smith	22
Ratio of the Cylinders of a Compound Engine and what takes place in them	Wm. Hemphill, '00	31
Thomson Recording Wattmeter	C. G. Carmichael, '01	49
Portland Cement vs. Bone Ash Cupels	H. Roy Stovel	56
Peat	Arthur G. Ardagh	59
The Conservation of Water for Power Purposes.	C. H. Mitchell, A.M. Can. Soc. C.E.	64
Some Notes on Greater Ontario	E. V. Neelands, '00	81
The Madison Draw Bridge at Portland, Oregon.	H. G. Tyrrell, C.E., '86	89
Handling Daylight	W. J. Withrow	124
Air Brakes	W. E. Foreman, '99	133
Signaling	R. Latham	163
Index to First Fourteen Numbers		199

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Charlton, H. W., B.A.Sc., '97.
Chubbuck, L. B., '99.
Clark, J. T.
Clark, N., '01.
Clark, J., '00.
Clarke, F. F., '00.
Clothier, G., '99.
Collins, C. D.
Connor, A. W., B.A., '95.
Cooper, C., '99.
Coulthard, R. W., B.A.Sc., '99.
Craig, J. A., '99.
Conlon, F. T., '02.
Chace, W. G., '01.
Christie, A. G., '01.
Cockburn, J. R., '01.
Darling, E. H., '98.
Davison, J. E., '00.
De Cew, J. A., '96.
Dill, C. W., '91.
Dixon, G., '00.
Dickenson, E. D., '00.
Dixon, H. A., '00.
Dunbar, M.
Duff, W. A., '01.
Elliott, J. C., '99.
English, A.B., '90.
Evans, J. W.
Eason, D. E., '01.
Fairburn, J. M. R., '93.
Finch, H. J. W.
Fingland, W., '93.
Foreman, W. E., '99.
Forester, C., '93.
Forward, E. A., '97.
Fullerton, C. H., '00.
Gagné, L., '01.
Garland, N. L., '90.
George, R. E., '02.
Gibson, N. R., '01.
Gordon, C. B.
Grant, W. F., B.A.Sc., '98.
Gray, R. L.
Guernsey, F. W., '95.
Guest, W., '00.
Gurney, W. C., '96.
Guy, E., '99.
Hall, G. A.
Hamer, A. T. E., '01.
Harvey, C., '01.
Hanning, G. F., '89.
Henderson, S. E. M., '00.
Hemphill, W., '00.
Henry, J. A., '00.
Henry, J. S., '02.
Herman, E. B., O.L.S., D.L.S., '86.
Hudspeth, W. S.
Innes, W. L., O.L.S., C.E., '90.
Irwin, C. A., '95.
Jones, J. E., '94.
Jackson, F. C., '01.
Johnson, H. A., '00.
Johnson, J. C., '00.
Johnson, J. A., '00.
Laidlaw, J. G., B.A.Sc., '93.
Laidlaw, A.
Laird, R., O.L.S., '86.
Laing, W. F., '96.
Langley, C. E., '92.
Latham, R., '99.
Lash, N. M., '94.
Lavrock, G. E., '98.
Little, F. J.
Lumbers, W. C., '00.
Marani, V. G., '93.
Matheson, W., '01.
Mace, F. G., '02.
Meadows, W. W., O.L.S., '95.
McArthur, R. E., '00.
McAree, J., O.L.S., D.L.S., B.A.Sc., '82.
McCullough, A. L., O.L.S., '87.
McDougall, A. C., '01.
McDowall, R., O.L.S.,
McFarlane, G. W., O.L.S., '88.
McIntosh, D., '98.

Ordinary Members—*Continued*

McKenzie, J. R., '00.
McMurchy, J. A., '96.
McMaster, A. T., '01.
McMillan, G., '01.
McMillan, J. G., '00.
McLennan, A. L., '02.
McMichael, C.
McNaughton, F.D., O.L.S., '98.
McVean, H. G., '01.
Milne, C. G., B.A.Sc., '92.
Miller, L. H., '00.
Monds, W., B.A.Sc., '99.
Moore, F. E.
Morris, J. L., O.L.S., C.E.,
Morphy, E. J.
Nicholson, C. J., '94.
Paterson, J., '99.
Perry, F. N.
Playfair, N. L., '92.
Pope, A. S. H., '99.
Phillips, E. H., '00.
Price, H. W., '01.
Revell, G. E., '99.
Ritchie, N. T., O.L.S.
Rodger, J., O.L.S., '87.
Robertson, J. M., '93.
Robinson, A. H. A., B.A.Sc., '97.
Roper, W. P.
Ross, J. E., O.L.S., '88.
Roundthwaite, C. H. E., '00.
Russell, R., '93.
Russell, W., '91.
Saunders, G. A., '99.
Saunders, H. W., '00.
Shanks, T., B.A.Sc., '99.
Shaw, J. H., O.L.S., '98.
Smallpiece, F. C., '98.
Smillie, R., B.A.Sc., '97.
Smith, A. D., '92.
Smith, R., '98.
Spotton, A. K., '94.
Stacey, G. E.
Stewart, J. A., M.A., '98.
Stull, W. W., O.L.S., B.A.Sc., '97.
Tennant, D. C., '99.
Tennant, W. C., '00.
Taylor, A., '00.
Thorold, F. W., '00.
Thorne, S. M., '00.
Troupe, W. J.
Tyrrell, W. J., O.L.S., D.L.S., C.E., '83.
VanEvery, W. W., '99.
Vercoe, H. L. '98.
Wagner, W. E., B.A.Sc., '99.
Watson, R. B., '93.
Watt, G. H., '99.
Weekes, M. B., B.A.Sc., O.L.S., '97.
Weir, H. M., '00.
Weldon, E. A., '97.
White, A. V., '92.
Whitson, J. F., O.L.S.
Withrow, J. D., '00.
Willson, R. D.
Wickett, T., '89.
Wiggins, T. H., O.L.S.,'90.
Wilkinson, T. A., '98.
Williamson, D. A., B.A.Sc., '98.
Withrow, A. J., '90.
Withrow, F. D., '00.
Woolverton, C. E,
Wright, R. T., '94.
Wright, T. D.
Yeates, E. G., '99.

Undergraduate Members.

Acres, H. G., '03.
Algie, J., '03.
Angus, H. H., '03.
Barber, H. G., 02.
Batt, T. W. '02.
Beatty, F. R., '02.
Beatty, J. A., '03.
Begg, A. W., '03.
Belton, C. H., '03.
Blair, W. J., '02.
Bonnell, M. B., '03.
Breslove, J., '02.
Brown, G., '03.
Brown, J. M., '02.
Bryce, R. B., '03.
Burgess, E. L., '03.
Burley, R. J., '03.
Burnham, F. W., '03.
Burwash, N. A., '02.
Campbell, A. R., '02.
Campbell, W., '02.
Challies, J. B., '03.
Charlebois, J. P., '03.
Christie, W., 02.
Connor, H. V., '02.
Corbett, J. T., '03.
Corrigan, T. E., '02.
Costin, W. E., '02.
Coulson, C. L., '03.
Culbert, M. T., '02.
Cumming, R., '02.
Davison, A. E., '03.
Depew, H. H., '03.
Douglas, W. E., '02.
Dunlop, R. J., '02.
Eakins, S. W., '03.
Edwards, W. M., '02.
Elmsley, B. R., '02.
Elwell, W., '02.
Empey, J. M., '02.
Evans, H. W., '03.
Fensom, C. J., '03.
Fleck, J. G., '03.
Fuce, E. O., '03.
Fuller, V. M. S., '03.
Gaby, F. A., '03.
Gardner, J. C., '03.
Gibson, A. E., '02.
Gillespie, P., '03.
Goodwin, A. C., '02.
Gordon, E. R., '03.
Gordon, J. P., '03.
Gourlay, W. A., '02.
Gray, A., '03.
Green, E. A., '03.
Greenwood, W. K., '03.
Gurney, E. H., '03.
Gzowski, H. N., '03.
Hamilton, J. F., '03.
Hanes, G. S., '03.
Harcourt, F. T., '03.
Hayes, L. J., '03.
Henderson, F. D., '03.
Hendry, M. C., '03.
Henwood, C., '02.
Horton, J. A., '03.
Irving, T. C., Jr., '03.
Jackson, J. G., '03.
Jackson, J. H., '03.
James, E. A., '03.
Johnston, D. M., '02.
Johnston, C. K., '03.
Johnston, H., '03.
Keagey, J. W., '03.
Knight, R. H., '02.
Kernahan, M. G., '03.
Lang, A. G., '02.
Langmuir, F. L., '02.
Larkworthy, W. J., '03.
Latournell, A. J., '03.
Legge, A. H., '03.
McAuslan, H. J., '03.
McBride, A. H., '02.
McCuaig, O. B., '03.
McFarlane, J. A., '03.
McGuire, R. A., '03.
McKay, J. J., '02.
McKay, J. T., '02.
McKellar, J. O., '03.
McKitrick, C. W., '03.

McKinnon, H. D., '03.
McNaughton, A. L., '03.
Madden, J. F. S., '02.
Mathieson, P., '02.
Maher, W. R., '03.
Marriott, F. G., '03.
Marrs, C. H., '02.
Meader, J. E., '03.
Milden, A. J., '03.
Miller, M. L., '03.
Mills, J. E., '03.
Milne, W. G., '03.
Montgomery, R. H., '03.
Mans, C. A. '05.
Moore, F. A., '02.
Morley, R. W., '02.
Morton, P. E., '03.
Mullins, E. E., '03.
Nash, T. S., '02.
Nevitt, I. H., '03.
Oliver, E. W., '03.
Oliver, J. P., '03.
Pace, J. D., 03.
Pardoe, W. S., '03.
Paris, J., '03.
Patten, B. B., '03.
Philip, H. D., '03.
Plunkett, T. H., '03.
Pinkney, D. H., '03.
Porte, W. B., '03.
Powell, G. G., '02.
Ratz, W. F., '02.
Robertson, D. F., '02.
Robertson, H. D., '02.
Rose, H. G., '03.
Ross, R. B., '03.
Roy, J. E., '02.
Rutherford, F. N., '03.
Shipe, H. M., '03.
Sinclair, D., '02.
Small, H. S., '03.
Smith, H. G., '03.
Smith, J. H., '03.
Steele, D. L., '03.
Steele, T. J., '02.
Stevens, W. A., '03.
Sutherland, W. H., '02.
Taylor, T., '02.
Teasdale, C. M., '02.
Thorne, W. F., '03.
Townsend, C. J., '03.
Trees, S. L., '03.
Umbach, J. E., '03.
Waldron, J., '03.
Wass, S. B., '03.
Wanless, A. A., '02.
Weddell, R. G., '03.
Whelihan, J. A., '02.
White, F., '03.
Wilson, J. M., '03.
Wilson, N. D., '03.
Williams, C. G., '03.
Worthington, W. R., '03.
Young, C. R., '03.
Young, W. H., '03.
Zahn, H. T., '02.

OBITUARY NOTICE.

It is with regret that we have here to chronicle the death of one of our undergraduate members, Mr. G. C. McCollum, a student in the Mechanical and Electrical department of the Third Year. Mr. McCollum was the eldest son of ex-Mayor J. R. McCollum, of Welland, Ont., and was twenty-two years of age. He took ill on Thursday, December 20, 1900, and after two weeks of pain died at Toronto General Hospital on January 4. Interment took place with military honors at Welland, on January 7.

Mr. McCollum was a lieutenant in the 44th Welland Regiment. Among his fellows always popular, his decease robbed us of a friend and fellow student.

ENGINEERING SOCIETY

—OF—

The School of Practical Science

TORONTO.

PRESIDENT'S ADDRESS.

GENTLEMEN:—

It affords me much pleasure to welcome you to the opening meeting of our Society.

To those of you who are about to become members, I extend a hearty welcome, while to the older members who have elected me to the highest position in their power I extend my thanks.

You have conferred a great honor upon me in electing me to the office of President, and I sincerely trust that, with the co-operation of the energetic committee which you have elected to assist me, the Engineering Society will continue to prosper as in the past.

It is necessary that each member should do his share in assisting the committee to make this year one of the most successful in the history of the Society.

The objects of the Society are already set forth in the Constitution, copies of which may be obtained from the librarian.

I would like particularly to emphasize the great value to be derived from reading papers at the meetings of our Society. The student members are beginning to take an active interest in this important branch of the School work and those who have read papers in the past will all state that they are exceedingly glad they did so.

Since we recognize no year distinctions, and all papers on engineering subjects are acceptable from our members, I trust that you will carefully consider the many advantages gained and continue to contribute towards the contents of our pamphlet.

Don't let the thought that you are not a senior student keep you from contributing a paper, for it is at our meetings that we have to become more thoroughly acquainted with each other.

As President of the Engineering Society I have to procure the papers to be read at our meetings and published in the pamphlet and I can assure you from my experience this summer that this is no easy task.

There should be no reason why it should be difficult to secure papers from the undergraduate members unless it be that they are not fully aware of the benefits to be derived therefrom.

There are a great many reasons why you should avail yourselves of the opportunity offered to contribute papers and read them at the meetings, and with your permission I will mention a few of these.

The Council of the School, when granting honors, consider the papers read before the Society, so that not only those who listen but also the writer receives much benefit.

One other great advantage of reading papers at our meetings, which is very often overlooked, is that the reader gains considerable confidence in speaking in public. No doubt a number of you will be called upon, at some time in the practice of your profession, to state your views and support them before a meeting of directors of some company or a Town Council. A great deal more weight is attached to a person's opinions if they are given forcibly and without effort, and at our meetings you have a splendid chance to become more proficient in this branch of your profession.

Another advantage gained in compiling a paper is the knack of arranging your material in proper systematic order, which is so essential in the work of the engineer. The notes taken, the extra reading, the concentration of the mind on the subject, and the opinion of your fellow students on your efforts are also of advantage.

After a paper is read at our meetings I would like you to have questions to ask and if possible create some discussion, for in this way many points are brought out which may have been overlooked in the paper.

Last year we were very fortunate in having several of our papers illustrated with lantern slides which were generously supplied by the School. In this respect I might say that a considerable amount of time was expended by some members of the Faculty and the Fellows. In particular I wish to thank Mr. C. H. C. Wright and Mr. A. H. Harkness for their untiring efforts in providing us last year with so many lantern slides, and I trust that this year we may look forward to seeing more of the slides on the screen.

After the papers have been read at our meetings they are filed away until it is time to arrange the material for the pamphlet. They are then submitted to the Editor, who has charge of the publication, and is appointed by the Council of the School, who selects those most suitable for publication in the proceedings of the Society.

Last year 1,500 copies of the pamphlet were printed. Copies of this were sent to all life members of the Society, and all the prominent magazines and colleges in the world. We also make exchanges with a few similar societies in other colleges.

The Engineering Society handles all the draughting paper and laboratory note books used in the School. This year we will purchase our note books direct from the wholesale, but I am sorry to say this is impossible with the draughting paper, as the paper we use is manufactured in Germany At a meeting of the committee held last May we discussed the advisability of purchasing our paper direct from Germany, but had to give up this idea on account of the lack of funds in the treasury. A great saving in the cost of the paper could be made if we had the necessary money to order our season's stock direct from the manufacturer in May.

This matter has received careful consideration, and the problem of increasing our funds was constantly with me during the past summer. During next summer if each member of our Society both graduate and undergraduate, could obtain an advertisement

to be inserted in our annual pamphlet, the finances of the Society would be placed in such a secure state that we could then buy all our materials direct from the manufacturers. This would mean that our funds would be further increased. There is no reason to reduce the cost of the materials now sold to the students, as they are now below the prices of the retail dealers. This then would mean that we would be able to spend a considerable sum annually in purchasing new and up-to-date books for our library. We could easily spend a few hundred dollars in this work, and it is my opinion that the money could not be spent in a better way. The first object of the Society, as stated in Article 2 of our Constitution, is "the encouragement of original research in the Science of Engineering," and this cannot be encouraged in a more practical way than in providing literature on various scientific subjects for the use of the members of our Society.

I trust that next summer you will avail yourselves of the opportunity thus afforded of helping to place the library of the Engineering Society in a condition that it will be of use to our members.

At our last annual meeting, Mr. Shanks, the retiring President, introduced a new system of voting, which gave such general satisfaction that I feel I cannot conclude without mentioning it. By-law four of our Society states that "a majority of the total number of votes cast shall be necessary for election to any office." When there were over two candidates for any office, under the old system of voting, this would very often make it necessary to hold two or even three elections before one candidate would receive a majority of the votes cast. This caused an annoying delay in the elections and a great deal of unnecessary trouble and work to the scrutineers as well as to the members.

In the new system this was overcome by the voter marking opposite the candidate for whom he wished to vote the figure 1, while opposite his second choice for this office he marked the figure 2, and opposite his third choice the figure 3, and so on. When the number of "first choices" were added, if any candidate had received a majority he was declared elected, but if not then the "second choices" of the lowest candidate were distributed among

the others. If no candidate was then elected the ballots of the lowest candidate were again distributed among the others.

This system was very satisfactory and little more trouble was experienced in counting the ballots than in the ordinary way, and an election was always assured.

Before concluding I would like to make a few remarks about the School. The reputation of the Ontario School of Practical Science, as an engineering college, has been rising for a number of years, until now it is looked upon as being one in which a very thorough knowledge of the foundation of engineering science is obtained. The number of students in attendance has been increasing rapidly each year and it has arrived at the point where very little more accommodation can be afforded. It is crowded in every department and in a year or two if more accommodation is not provided the students will have to go to other colleges to obtain their education.

A large grant from the Government is needed to maintain the high reputation which the School now enjoys, and to accommodate the students who are flocking here annually.

It is with regret that I have to refer to the illness of one of the Past Presidents of our Society, and a member of the Faculty of the School. Mr. Duff has always taken a keen interest in the Engineering Society, but unfortunately will not be able to be with us this year. I am glad to be able to announce that he is very much better and hopes to continue his work in the School next fall. I am sure that it is the wish of every member of the Society that Mr. Duff's health and strength will soon return to him and that he will again be able to continue his lectures and attend the meetings of our Society.

I will conclude my remarks by again thanking you for the honor you have conferred upon me, and will ask that you do all in your power to help the committee make this one of the most successful years in the history of the Society.

F. W. Thorold.

CHEMICAL WOOD PULP.

J. A. Decew, '96.

In preparing this paper on Chemical Wood Pulp, I have merely attempted a synopsis of the subject, which may convey to those who heretofore have given the subject but little attention, some idea of the methods employed and the chemistry involved in this industry. It is needless to mention that as far as our broad Dominion is concerned, this industry is but in its infancy, for the larger portion of our northern, uninhabited lands are well timbered with spruce, which is one of the best of the paper making woods. Consequently this subject demands more attention than it receives from Canada's Practical Science students, because it has already taken a deep hold upon the financial world, and because our profession above all others, should keep in touch with the industries of the country.

The word pulp is a term which generally may be applied to a number of materials, which are quite variable in character but more or less similar in appearance, therefore if we first classify these in a general way, we shall have a somewhat clearer conception of that special kind, that we are about to discuss. We may divide them into four classes according to quality, namely:

I. Rag Pulp—which is made from cotton, linen or hemp fibres.

II. and III. Wood Pulps—which are of two kinds, chemical and mechanical.

IV. Straw Pulp—which is a chemical product of inferior quality.

As the manufacture of mechanical wood pulp was very ably described in a paper read before this Society last year, the subject matter of this article will deal exclusively with its half-brother of the chemical species, which is in reality another product from the same substance.

Mechanical pulp is simply wood, ground to a fine powder and consists chemically of a combination of celluloses and lignocelluloses. Now if instead of grinding, we treat the wood with a chemical solution, which disintegrates it and dissolves out the lignocelluloses, we then have left what is commonly called chemical pulp, and this consists of those celluloses which have resisted the action of the solvent. As about half of the woody substance is thus removed and destroyed, the remaining product must necessarily be more costly than the ground pulp, but the fibres remaining are white and unbroken and are only comparable with the cheaper product when quality is not required. Mechanical pulp has a very short fibre, little felting power, is quickly discolored in air and light, and is only used as a filling material in news, wrapping, and other papers of a temporary character. Chemical wood pulp, however, makes a good, white, permanent paper, and is the source of most of our writing materials, although it makes neither as strong nor as resistant a paper as do the rag pulps.

The pulps prepared from straw are pronounced oxycelluloses, and have considerably more chemical activity than those prepared from the woods.

There are two distinct methods of preparing the chemical wood pulp, which may be designated as the alkaline and the acid. In the alkaline or soda process the usual method employed is to pack the wood in the form of chips into a horizontal cylindrical, rotating digester, which has a capacity of about three cords.

Here it is digested, with about seven hundred gallons of a six to nine per cent. solution of sodium hydrate, which is heated to high temperatures by means of live steam. The boiling lasts from eight to ten hours, at pressures which may vary from sixty to two hundred and ten pounds per sq. in. The products resulting from this "cook" are a grayish brown pulp and a dark brown liquor, which are dumped into iron washing tanks, and after the liquor is drained off, the pulp is thoroughly washed. But as these wash waters are finally evaporated in order to recover the contained soda, they are used until they become quite concentrated, the pulp being washed continuously with a less concentrated solution until all the alkali is removed. The pulp is now treated with a bleaching solution, which contains twelve to fourteen pounds of bleaching powder

for every hundred pounds of pulp, and this removes the remaining ligneous matter, leaving a pure white cellulose.

The recovery of the soda from the waste liquor is accomplished by evaporation in vacuum pans until it has a density of 40° Baume, when it is burned in a special furnace to remove the organic matter. The remaining ash contains the soda in the form of a carbonate, and when this is heated in tanks with slaked lime, in the proportion of one hundred of soda to sixty of lime, the lime is precipitated as calcium carbonate and the soda becomes caustic again.

Another method of recovering the soda, which has been lately adopted, consists in heating three parts of ferric oxide with one of soda carbonate, when sodium ferrate is formed. And on heating this with hot water, it decomposes forming sodium hydrate and ferric oxide once more. The liquors of the alkaline process, sometimes contain large quantities of the sulphate or carbonate which are cheaper although weaker in action than the hydrate. In addition to the recovery of the soda from these liquors, a valuable product in the form of acetate, may be obtained from the organic matter of the solution. As perhaps you are aware, one of the standard methods for the manufacture of oxalic acid, is the treatment of wood or sawdust with alkaline hydrates at temperatures ranging from 200° to 250° C.

Now if the heating is prolonged and oxidation is allowed to take place, either from contact with air or oxidizing agents, a large percentage of acetic acid is formed. Therefore if the soda liquor is evaporated and charred at temperatures from 350° to 400° C. the organic matter reacts with the soda to form sodium acetate ($Na\ C_2\ H_4\ O_2$, $_3H_2\ O$). This product comprises about 38 per cent. of the soluble portion of the char, and about 16 per cent. of the residue. With Esparto liquor five to six per cent. of the weight of the original fibre was obtained.

In the soda process poplar is largely used, although maple, cottonwood, white birch and basswood, are also employed. The spruce, pine and hemlock yield a long fibre but are a little more difficult to treat. The main objections to the process are—

1. The high temperatures and pressures required.

2. The formation of dark colored products which are difficult to remove from the pulp.

3. The destructive action that the alkalis have on the celluloses themselves, as the less resistant are attacked and dissolved in the severe treatment required to remove the ligneous portion.

The acid or sulphite process:—

This is the process which is now being most commonly introduced into this country, because it has several important advantages over the alkaline treatments just described. In the first place, the cost in chemicals is less; and a larger yield of fibre is obtained, which is not weakened by the treatment.

And secondly, the paper, which is made from this pulp, is harder and more transparent and durable than that from wood pulps made by other methods.

The treatment consists in digesting the wood at high temperatures with an acid sulphite solution.

The acid radical unites with the products of hydrolysis to form soluble sulphonated derivatives, while the base unites with the acid products of the decomposition. The hydrolitic action is greatly increased by the presence of sulphurous acid, and for this reason, the bi-sulphite ($Na\ H\ SO_3$) solution effects a reduction in less time, and at lower temperatures, than a neutral sulphite solution would.

Now, turning our attention to some of the details of the treatment, we find that the bark and knots and also the resinous matters of the wood, are very slightly acted upon by these sulphite solutions, and must in consequence be carefully removed. Sound knots may be allowed to pass through the digester and be afterwards removed from the pulp by screens. Before very high temperatures are reached it is necesesary that the wood be thoroughly impregnated by the solution, and the absorption is hastened by previously crushing the wood. Dry and green woods, or woods of different species, should not be treated together in the same digester as they will be unequally reduced and leave chips in the pulp.

The first step in the preparation of the sulphite liquor is the formation of sulphur dioxide (SO_2) from the combustion of either

sulphur or its compounds. As this gas must be absorbed by water to form sulphurous acid ($H_2 SO_3$), it is evident that the less it is diluted with other gases the more complete will be its absorption. Therefore the sulphur is burned in specially constructed furnaces with the object of obtaining a complete combustion with the smallest possible draught. If the combustion of the sulphur is incomplete, a part of it sublimes and re-acts with the sulphur dioxide to form thiosulphuric acid ($H_2 S_2 O_3$) which in turn forms thiosulphates. These will decompose on boiling, and precipitate the sulphur into the pulp, which, being practically insoluble, it is impossible to remove. When this sulphur becomes oxidized to sulphuric acid it is very injurious to the paper making machinery as well as the pulp.

When pyrites is used in the production of sulphur dioxide more complicated burners are used, and additional care is taken to avoid overheating, for slags are easily formed which impede the draught and are difficult to remove. Blowers or exhaust fans are used to improve the draught through the furnace, and these cause a lot of fine dust to be carried over with the burned gases. This dust never reaches the pulp however, as the gases pass directly from the furnace into a dust chamber where it settles before the gases enter the cooler.

From the fact that one volume of water at zero centigrade will absorb sixty-nine volumes of sulphur inoxide; and at forty degrees will absorb but seventeen volumes, it is evident that the temperature of both gases and liquor will be kept down as much as possible during absorption. In practice the temperature of the cooler varies from ten to fifteen degrees. The absorption apparatus are of two kinds, namely, that in which the gas is absorbed by water holding the base in suspension or solution; and that in which the gas and water react together upon lumps of the carbonate of the base. The latter method, which is the older and simpler, consists of a high shaft or tower packed with limestone or dolomite, which is covered by a thin film of water that enters from above. The gases enter the base of the tower under pressure sufficient to force them up through the limestone and out at the top. The sulphur dioxide meeting the moist limestone, reacts with it, forming at first sulphurous acid ($H_2 SO_3$), and then calcium sulphite

($Ca\ SO_3$), while this insoluble product unites with more sulphur dioxide to form calcium bi-sulphite [$Ca\ H_2\ (SO_3)_2$], which being soluble is washed out by the descending water. The former or tank apparatus is the one generally used in this country, and consists of a series of tanks filled with water which holds the carbonate in solution or suspension.

In this case the chemical reaction is practically the same as just described, for as the sulphur dioxide is absorbed, the insoluble calcium sulphite is precipitated, but becomes redissolved as it reacts with more sulphur dioxide to form the bi-sulphite [$Ca\ H_2\ (SO_3)_2$]. In practice more or less of the insoluble sulphate ($Ca\ SO_4$) is formed by oxidization, which is allowed to settle and then the liquor is drawn off and stored in air tight, lead lined tanks, until it is required for use.

The real process of pulp making begins when the chips and liquor are brought together in the digesters, which vary in size, and may be either upright or rotary. But the great difficulty in making digesters for this process, is to obtain a suitable lining which will protect the iron plate from the corrosive action of the sulphurous acid. The usage in the past has been generally in favor of lead linings, as they are but slighted acted upon by the acid, and are further protected by the coating of lead sulphate which forms. The objection to the use of lead, to overcome which many devices have been tried, is the fact that it has about double the co-efficient of expansion of iron, so that in alternate heating and cooling, it buckles and draws to such an extent as to soon necessitate repairs.

Bronze linings have been used with some success, and boiler scales in the form of sulphite of lime or silicates of iron and calcium have worked very well.

But the digester lining that takes the precedence and which is now being rapidly introduced, is merely a layer of Portland cement of about four inches in thickness, and this may be applied to the boiler directly or first made into slabs and then fitted in. At first it is more or less porous, but the interstices are soon filled by a deposit of sulphate and sulphite of lime which render it quite impervious. The cheapness of the application and repair of this lining will recommend its general adoption.

In a digester containing two cords of chips, about twenty-five hundred gallons of a three and one-half per cent. liquor is used. The temperature is raised slowly until after the wood has become saturated with the liquor, and then a steam pressure of sixty-five to eighty-five pounds is turned on, which is equivalent to a temperature of one hundred and fifty-five to one hundred and sixty-five degrees centigrade. At these high temperatures the bisulphite is decomposed into sulphurous acid, and the normal sulphite, which being insoluble is deposited in the pipes or pulp. The sulphurous acid gas forms a hydrostatic pressure, which, added to that of the steam for the given temperature, gives the total pressure in the boiler.

Thus the pressure may be considerably increased, by the formation of this gas, without an equivalent rise in temperature. On account of the greater convenience the digesters are heated by means of live steam, which, by condensing in the pulp, is continually diluting the solution, but by employing a non-conducting jacket very little difficulty is experienced in practice, especially when cement linings are used.

At the end of the cook the gas is nearly all blown off and then the pulp is blown out under a pressure of about thirty pounds. This saves time in handling and the trouble of beating. It must now be thoroughly washed to remove any of the precipitated sulphite, especially when bleaching is to follow, for the sulphite is a strong antichlor itself, as it takes up the free oxygen formed by the action of the chlorine.

The pulp is never a pure, permanent white until after the ligneous and coloring matters remaining, have been broken up and removed by the action of a bleaching agent. The true bleaching action is purely an oxidization, which breaks up the coloring matters into simple colorless oxidized derivatives. With bleaching powder ($Ca\ O\ Cl_2$) the chlorine unites with the hydrogen of the water and this action liberates the oxygen which does the work. Pure oxygen, ozone or hydrogen peroxide, may also be used with equal effect. On the other hand the bleaching action of sulphurous acid is of a quite different character, for it combines with the coloring matters to form colorless compounds, which are easily reduced with a return of the color when the acid is neutralized.

You will naturally wonder what becomes of the waste liquor in this process, and this is one of the problems that has been left for this century to decide. In some places the gas is recovered but the general practice is to dump the liquors into the nearest pond or stream to get rid of them. This not only means a loss of half the woody structure and the gas in solution, but the effect of these liquors in fishing streams is remarkable. The sulphurous acid being a reducing agent, combines with the free oxygen in the water, and the organic paste in the solution forms a coating over the gills of the fish; therefore the fish have left no atmosphere and could not breath it if they had. If the waste liquor is evaporated the residue has no fuel value, therefore we must look in other directions for methods of conversion into valuable bi-products. All that is known concerning the chemical composition of these liquors, is that they are sulphonates containg the OCH_3 group. Future research may result in the manufacture of either glucose, alcohol, oxalic or acetic acid, from this organic residue.

Resinous woods are not very suitable for pulp making, as the resins are insoluble in hot bi-sulphite solutions, and although they are dissolved by the alkaline solvents, every hundred parts of resin will neutralize eighteen parts of the alkali.

Woods such as chestnut, which contain tannin, should not be treated by the sulphite process, as the tannic acid would act as an oxidizing agent, converting the sulphurous into sulphuric acid. Spruce and poplar are used almost exclusively in the sulphite process.

If a compound cellulose such as wood is treated with water at a high temperature, a hydrolitic action takes place with the partial isolation of cellulose and the formation of soluble compounds with an acid reaction. All of the commercial methods of isolating cellulose depend upon this hydrolitic action. The soda process is a basic hydrolysis, and the sulphite process is an acid hydrolysis, although the chemical reactions that actually take place in the cellulose molecule, are yet but a matter of conjecture. The emperical composition of cellulose is the same as starch ($C_6 H_{10} O_5$), but they differ remarkably in resistance to hydrolysis and in many other ways. This indicates a difference in the linking of the

unit groups, and in the reactivites of the OH groups, which in cellulose exercise a purely alcoholic function. The investigations of Cross and Bevan indicate that the cellulose formula is $C_6 H_6 O (O H)_4$, or some multiple of this which is in a more or less hydrated condition, according as it is more or less resistant to hydrolitic action. All those celluloses that are eaten and digested by the herbivora are extremely hydrated forms, and they become more resistant to external agencies as the water of hydration is removed. This fact is well exemplified in the discriminating way that fodder eating animals usually select their foods.

THE BONDING OF BROKEN STONE ROADS.

A. W. Campbell, C.E.

Before entering upon the subject which I have brought before you today, in the title of this paper, it will be well to review briefly the construction of a broken stone road. In general, the first step in the construction of a broken stone road of modern design is to prepare the natural sub-soil, on which the stone road surface is to rest, so as to make of it a firm and strong foundation. This treatment of the sub-soil for the most part, is a matter of grading and under drainage, especially the latter. It is the natural soil which must bear up the weight of traffic, and a wet, yielding foundation is not a suitable support, when bridged over with any form of paving material. With the exception of light, and partly decayed vegetable mould, nearly all soils, when kept dry by underdrainage, are sufficiently strong to support the heaviest traffic, but when saturated with water, every soil is weakened. Natural drainage is frequently sufficient, so that artificial under-drainage, usually of common porous tile, is not always necessary. The kind of soil, whether clay, gravel, sand, loam, and the facilities and need for drainage will indicate the means to be adapted.

An excavation is made to receive the stone; if a town or city street, curbing is placed along the sides; the sub-soil is thoroughly consolidated with a roller, and upon this is placed the stone, broken into fragments varying in size from stone dust and screenings to such as will pass through a 2½ inch ring. If the traffic is great, or if the soil is of a kind particularly difficult of drainage, as for example what is described as an "oily clay," a Telford foundation is particularly useful. A Telford foundation is composed of stones of varying sizes, not exceeding ten inches in length, six inches in breadth on the broadest side, nor four inches in thickness on the narrow side. These stones are placed lengthwise across the road, breaking joints as much as possible; the interstices are filled with stone chips, all projecting points are broken off, and the whole structure is wedged, consolidated and made as firm as possible. As a cheaper means, the stones are commonly placed flat on the road,

closely together. The surfacing metal is then placed on this "pitched" foundation, in the usual way, usually to a depth of at least six inches, and for heavy traffic may have a depth of ten or twelve inches.

In placing this broken stone in the roadway it is spread in layers of about four inches in thickness, and a steam roller passed over each layer to consolidate them. The road surface should serve two ends. It should present a smooth, hard surface to traffic; and it should be impervious to moisture, so that rain falling upon it will not pass into, and soften the earth on which it rests. That is to say, it should answer the purpose of both a floor and a roof. These objects are attained by making the surface of the roadway higher at the centre than at the sides, so as to shed the water to the side gutters, and by compressing and compacting the material of which the road is composed. This compressing of the roadbed is usually performed either by traffic or by means of a heavy roller, aided by intermixing with the stone, certain fine stuff, screenings (the chips and stone dust created by crushing), sand, loam, street scrapings and even clay.

The use of a binding materal in the construction of broken stone roads, is a matter which has been the subject of much discussion, with a corresponding diversity of opinion. The kind of material, the amount, the method of using, forms an interesting chapter in the history of road-making, and it is to this, together with the use of a roller, to which the title of this paper draws attention.

The use of the roller, and therefore the bonding of the road, begins with the earth sub-soil. The roller used on the natural soil will serve two purposes; it will find the weak spots in the sub-soil; will consolidate it, and assist in providing a firm foundation. Unless the sub-soil is rolled, uneven settlement is likely to take place after the road is completed, creating depressions in the road surface, a matter obviously to be avoided. By rolling it, on the other hand, wherever there is a quantity of loose soil, created in drainage excavation, in filling, or is weak because of its composition, it will be forced down beyond the possibility of settlement. The earth sub-soil too, if given a crown similar to the finished surface

of the road, and its surface thoroughly hardened, will have, itself, a tendency to assist in the drainage of the road by throwing off such water as may percolate through from above.

When this is consolidated, it will form a hard and firm base, upon which to roll and consolidate the succeeding layers of stone. If the stone is merely placed upon an unconsolidated sub-soil, the result can readily be imagined; the stones are forced by rolling into the sub-soil, and the earth is worked up among the stones. The subsequent rolling is less effective, and whatever beneficial drainage would result from a smooth sub-soil surface is lost.

The sub-soil, then, having been thoroughly rolled, a Telford or other "pitched" foundation, if required, may be laid, and this also rolled. Upon this, the broken stone is placed. It should be spread in layers, and each layer thoroughly rolled. The thickness of the layers, as spread over the road for rolling, will vary in accordance with many circumstances, the weight of roller used, the size and hardness of the broken stone, the ultimate thickness of the road bed, etc. Six inches loose should be a maxim thickness, while three or four inches is preferable. Where the stone is graded, as it should be, into different sizes, each size of stone should be placed on the road and rolled separately. As an instance of what might be done, take the case of a layer of stone to be six inches in depth when consolidated, it would be most practicable to roll down two layers of four inches thickness, loose, which, when compacted will make about the required depth. The greater the depth of loose material under the roller, the less perfect will the consolidation be, and there is the possibility of its being crowded into heaps over which the roller cannot pass.

The effect of the roller on the stone mass is to wedge the stones against one another, interlocking them, and giving them a mechanical clasp, one of the other, which is not readily disturbed by traffic. The roller is now used in preference to the old-time method of merely allowing traffic to do this work of consolidation, and is absolutely necessary to the best workmanship. Without the roller, the sub-soil is much disturbed by the pressure of narrow tires and by horses' hoofs, before the surface protection becomes a

protection, an effect much increased by wet weather. Before consolidation is attained under traffic, the sharp angles of the stones, which materially aid in procuring a durable bond, will be worn off. Without a roller, too, the stone cannot, with the best results, be placed in the roadbed in graded courses, the largest stones in the bottom and the finest on top, for traffic over the loose material will intermix them, allowing the large stones to work to the top.

The objection to large stones, of say 2½ inches in diameter, at the surface of the road, is that they do not assume so firm a bearing, as will smaller stones; they are more readily disturbed by pressure at one corner or at one side and are apt to be found rolling loosely under the wheels, and feet of the horses, nor do the different sized stones, if at the surface, wear evenly, the smaller wearing more quickly than the larger, so that a roughened surface results. On the other hand, it is urged that the finer stones intermixed with the larger, will lessen the percentage of voids in the mass. While this is no doubt true, yet the presence of large stones at the surface becomes very objectionable, and it is probable that the voids in the mass may be sufficiently filled by other means.

Rollers may be operated by horses or by steam power. Horse rollers usually weigh four or five tons, but may be weighted to six or eight tons. Steam rollers for broken stone roads weigh from eight to twenty tons. The objection to a heavy roller is that it cannot be used in soft material, as it bunches the earth or stone, creating mounds over which the roller cannot pass. An excessively heavy roller crushes the stone into position, breaks off the sharp angles, instead of working the stones gradually into a wedged condition. The heaviest roller, too, is apt to injure gas and water mains if at shallow depths, and they strain bridges, culverts and crossings. In a number of English cities, London among these, eight ton rollers are employed to prevent injury to city gas mains. Very light rollers, however, do not do the work of consolidation so quickly or perfectly as will one of moderate weight. Ten, twelve and fifteen tons will render the best service, twelve being a good standard. Where under-ground pipes, culverts, etc., are not a consideration, and two rollers are obtainable, a light roller for the loose material, and a heavy roller to complete the consolidation will

give the best results. Horse rollers are not desirable, as they are too light, and the efforts of the horses to move them disturb the loose metal very much. This last objection would not be so great if the horses were always well-trained, and the drivers understood their work; but, particularly in starting the roller, or on grades, the horses are not apt to pull together and their clumsy efforts before they get under way do very noticeable injury. While even in England, road rollers are not in use by all corporations, there remains no doubt as to their being essential to the most successful and economical results.

The percentage of voids in loose crushed stone varies according to the size of the stone, and whether or not the stone is screened into grades of equal size. The smaller the stones the greater the percentage of voids, and if graded the percentage of voids is also greater than where the stones are of unequal dimensions. For various conditions the percentage of voids has been found by experiment to range from 41% to 51%. For loose graded stones of 2½ inches diameter, the voids may be accepted as about one-half. The effect of rolling is to reduce the voids about one-half, leaving the per cent. of voids about one-third of the consolidated roadbed.

It is evident that to secure an impervious road covering which will protect the sub-soil from moisture, this considerable percentage of voids must be filled. "Nature abhors a vacuum," and unless the right material is used to fill the vacuum, the wrong material will be apt to force its way in. Without some material to occupy the space, the earth from below and the dirt from above will ultimately be forced and absorbed into it.

The materials commonly used for that purpose have been previously enumerated, stone screenings, sand, gravel, clay, loam, and street sweepings; but of these the two first are those most commonly employed. The manner of applying them is in general the same. A light coating of the binding material is spread over each layer of broken stone, is sometimes harrowed in, and the roller is then used.

The use of these materials as a "filler" is neglected in the name now applied to them, "binding materials." The real reason

for their use at all, by most engineers, is that they assist in producing a quick consolidation, less rolling being required than when they are omitted, of which the use of such materials as clay, loam and street scrapings is in evidence.

Of these materials as a "binder" the only one which receives the full approbation of the most reliable engineers, is screenings—the fine chips and dust produced in crushing. There is a quality possessed by this material which is exhibited by no other, that of cementing and re-cementing. This is a matter which of recent years has attracted much attention, and the quality of a stone as a road material is not to be judged merely by its hardness and toughness; but also by the cementing qualities of the dust. This dust is an important factor, it is supplied to the road in the first instance, it is constantly being created by the use of the road. It is in this way that limestone holds its place as a good road metal, for which it is apt to be soft. The dust possesses splendid cementing qualities making one of the most impermeable road surfaces. The dust of trap rock, ranks exceedingly well in this regard, which supplementing the hardness and toughness of the stone, makes it the most satisfactory for road purposes. On the other hand, granite, while hard and tough is lacking in cementing power, and is not as satisfactory as might be anticipated. Quartzite also is an instance of a poor cementing stone, and sandstone, unless bituminous, is also defective in this regard. So important is this quality considered by the Massachusetts Highway Commission, that they regularly test the stone used on the State roads for the cementing power of the stone dust, together with tests for absorption, impact and abrasion.

The use of foreign material, that is, all except stone dust, was strongly condemned by Mr. McAdam; in France, where road-making is more exactly studied than elsewhere, it is universally condemned, and the best practice of all countries forbids it. Clay, loam, and even sand, it is recognized, can only be used at the expense of the durability of the road. They assist in producing an apparently good roadbed with the least amount of rolling, but the bond is temporary, very subject to changes of weather, particularly wet weather, and alternate freezing and thawing, matters which

have to be carefully guarded against in this climate. When foreign "binders" are used, there is lacking in the road the firm mechanical inter-locking which continued rolling will produce; they lack the binding properties of stone dust; most of them are very absorbative of moisture, are even slippery, so that the stones are readily displaced by traffic, and a roughened and rutted surface ensues. In the time of a prolonged draught, foreign binding materials are most ready to contract, so that there is a tendency for the road to unravel.

The conclusion, therefore, which we come to is, that for bonding and inter-locking a broken stone road, first dependence should be placed upon the roller. For what it will not do in filling the voids, the dust and chips created in crushing the stone should be employed, bringing with them an added cementing value; foreign material, such as sand, clay or loam, can be included in the roadbed only at the expense of ultimate durability.

EXPLORING NEW ONTARIO.

ALEXANDER H. SMITH.

During the last session of the Ontario Legislature, a scheme was evolved for the exploration of unsurveyed lands north of the Canada Pacific Railway line, for information as regards the soil, timber, and mineral resources. For the purpose a sum of $40,000 was voted; and during the summer ten parties were organized to do this work. Eight of these were simply exploratory parties, the other two ran base lines as well as explored.

The exploration parties consisted of, in each case, a land surveyor, a timber and land estimator, a geologist, a cook, and men to act as guides and canoemen. The surveyor controlled and directed the work of the whole party, he also made a track survey of the principal rivers and lakes in the region, took notes on the meteorological phenomena and acquired information as to the soil and forest growth, the fish, fauna and flora.

The duties of the timber and land estimator were to note the kinds of forest trees and their dimensions, estimating their extent and the quantity in feet B. M. or in cords as the case might be. He also had to note how such timber could be transported, and if the streams were capable of floating such timber. As regards the land: he had to note the soil whether sandy, clayey, etc., and its capacity for growing crops, and of what kind.

The geologist took cognizance of the general topography of the country, its rivers, lakes, hills, and valleys, the rock formations, whether Laurentian, Huronian, or of later age; mapping their strike (if any), direction of contacts, and length and breadth of formation, where such could be made. Of necessity his chief work was to discover if the formations yielded any economic minerals, and to determine the kind and richness of such. Another branch of his work was to examine the fauna and flora and the Indian occupation.

The three officers of each party were required to keep careful field notes as well as diaries, and their whole object was to collect as much useful information as possible on the country that came under their notice. The region was so mapped out that the whole of it might be examined in one season, each party having a distinct territory to work in.

Early in June I was informed by Mr. Archibald Blue, Director of the Bureau of Mines, that I had been appointed Geologist to exploration party No. 8. This party had the region immediately to the west of Lake Nepigon, and the Nepigon river to Dog lake, up Gull river and the country around Black Sturgeon lake. David Beatty, O.L.S., of Parry Sound, was in charge, while John Piche, of Copper Cliff, was to act as timber and land estimator. Towards the end of June our party met at Collingwood and proceeded to Port Arthur by boat thence east to Nepigon Station on the C.P.R., where we started our work. During the greater part of the season our party consisted only of eight men, two of them being University of Toronto men who were anxious to see this grand country and try their prentice hands—and heads—at the noble arts of paddling, and "totting" supplies across rough trails and portages.

Our outfit consisted of four canoes, two Peterboroughs and two small barks; four tents and two tons of provisions, the estimate that was made in regard to the latter, being a pound and a half each of flour and pork a man per day. Of course other supplies were taken, such as sugar, raisins, rice, etc., this amount of provisions was calculated to last us about five months; only half the supplies were taken up to Lake Nepigon, where we started our work, the other half being stored at Nepigon Station.

Owing to a hitch in the forwarding of our supplies to Nepigon Station, our party was unable to proceed up the river for a number of days, so I accepted the kind invitation of Mr. Walter Beatty, M.P.P., to accompany him on a trip to the east side of Lake Nepigon to look at some mineral deposits he had seen there years before. By this I escaped the disagreeable wait at Nepigon. Mr. Beatty also arranged to send me across Lake Nepigon so that I could join my party at Gull river.

On the way up the river, we were fortunate enough to catch a number of the large speckled trout that make this region the most wonderful trout fishing place in the world.

Mr. Beatty was rewarded in his search by finding a large deposit of hematite, which I measured in a number of places and found to be over a hundred feet wide. The iron is banded with jasper and appears to be wholly in the Huronian formation, the lead running for a number of miles east and west. Since Mr. Beatty's discovery, there has been a regular stampede of local men into the region and numerous claims have been taken up, and other ranges parallel to it discovered. While on the east side of Lake Nepigon I saw what is known as the Shuniah silver mine, near Poplar Lodge. This deposit appears to be a green quartzite, containing native silver and galena. During my stay on the east shore I managed to get about sixty miles inland, and was thus able to see that the country was well wooded with good spruce.

I should not be at all surprised if valuable mines are opened up in this region when means for transportation are found. I believe there is a charter for an electric railway into this country, the power for operating it to be procured from the Nepigon river. The Sturgeon river, the largest flowing into Lake Nepigon, is quite close to the iron range, and is capable of producing a large amount of power when required.

Leaving Poplar Lodge, H. B. Co. post, on the east side, and after an all day and night's trip with two Indians across Lake Nepigon I reached Nepigon House, the Hudson's Bay's chief post on this lake. This trip shows how large a lake this is, as the Indians kept steadily at work, only resting now and again to eat. The lake in fact is about 80 miles long by fifty broad; the water is beautifully clear and very deep, and simply teems with speckled and lake trout, white fish, pickerel, pike and sturgeon. From Nepigon House another half day's trip brought me to Gull river, where I joined my party.

Our method of exploring was this; the surveyor made a track survey of all watercourses taken; this he did with a prismatic compass and a Rochon micrometer, generally using a ten link target. The disks—which were celluloid—were one foot in diameter, one

red and the other white. For short distances a small disk was attached to the centre of the pole, thus giving a five link base; for very short distances one disk itself answered. With this target, distances of a mile could be estimated with considerable accuracy, and a traverse of a lake or river could be made very rapidly, often seven or eight miles of crooked river being surveyed in one day. The track survey was checked by taking frequent observations for latitude and also for magnetic variations, in this way a fairly accurate map of the country could be obtained. This work generally employed five men, two for the disk canoe and two for the surveyor, supplies were moved in the canoes used for the traverse.

The timber estimator and myself made numerous explorations to the right and left of the track survey at distances of about five miles apart, walking inland five or six miles and very often remaining away from the camp all night. In these explorations our method was to take a straight compass line and time ourselves; we estimated that our progress was one mile an hour in a straight line; a good day's work being ten or twelve miles: now and again we used to take our blankets and provisions and walk inland all day, camping for the night, and returning the next day. In this way a good idea of the country on each side of the water route was obtained.

Any side water route that we had not time to survey would be explored by either the timber estimator or myself, taking for this purpose an Indian as guide. Distances were estimated either by eye, or timing, and compass readings taken, outlines of lakes and rivers being carefully mapped in the field book. For the purpose of these explorations our party was supplied with a Kay Taffrail log, an instrument very much like a trolling spoon in shape, tied to a long line. This spoon while revolving set in motion a register which registered the miles travelled. Unfortunately the first day I used it, a large pike mistook it for something good to eat and proceeded to bend the flanges of the spoon, and as the gauge for straightening them had not been sent, the instrument was practically useless. Another drawback to the instrument was the indicator, which refused to work after registering ten miles.

These canoe explorations sometimes led us long distances inland, taking three or four days, and often a week, to com-

plete; and it was often very difficult to calculate the exact amount of provisions to carry with one. Of course every unnecessary thing was left behind, and only the absolute necessities taken. Unfortunately I was unable to speak Indian very well, so when I left the main party I had to take two Indians, as I found out that with only one I was always in danger of having to turn back, as he would get very lonely and be afraid to venture farther inland, with two Indians they would keep each other company, and as long as they had enough to eat they seemed quite happy.

The equipment for three men on one of these explorations, constisted of pork, flour and tea, three tea tins, a pail, frying pan, blankets, and a canvas tarpaulin for a tent. All through the summer we never used a tent except when with the main party; the bulkiest part of our equipment would be, of course, our blankets. We generally depended on shooting enough partridge and ducks to help out the other provisions, and with these additions we were always able to cut down our supply of pork and flour. Some surprisingly accurate work was done with only estimated distances; three explorations I made between two fixed points showed an error of only a couple of miles when the exploration was plotted, although the distance travelled was very long, in one case about ninety miles. Two common errors can exist, first an inaccurate compass reading; and second a wrong estimation of the distance, but I found out that these errors had a happy faculty of compensating each other. In this work all portages were paced, allowing about twenty-five paces to the chain. It must not be thought that these side explorations were in any way correct, but they will be of some value to the further opening up of this country, as they will show fairly accurately a large number of canoe routes, the number and length of portages, and the general direction taken by the route.

Much valuable information was thus procured as regards timber, land, and the geological formations.

In calculating the amount of timber in the region explored, the method the timber estimator used was to pace off an average acre, estimate the average diameter of the trees and counting them, this was rather a tedious process, but then a fairly accurate determination of the timber in the region was procured. The number

of each variety of tree was noted, and their suitability for either lumber, pulp wood or railroad ties. The timber consisted of spruce, jack pine, poplar, white birch, tamarac, balsam, and occasional scattered groves of red and white pine and white cedar.

The character of the soil was noted by the exposures seen under the roots of freshly fallen trees, or by the exposures along the banks of small streams.

The areas and depths of any peat deposits were noted, an idea of the depth being obtained by means of a pole.

Outside the general work of exploring and mapping out the country, the geologist was required to get a general idea of the topography of the region, the main and subsidiary water sheds, the heights of mountains and hills, which he estimated by means of an aneroid, two of which were carried by the party.

Four series of rocks were met with in the region explored by party No. 8. The Laurentian, Huronian, Keweenawan and Animikie. Roughly mapping these, the Laurentian area, which was gneiss as a rule, is around Dog lake. Keweenawan formation immediately to the west of Lake Nepigon and Nepigon river, the Animikie along Nepigon bay and west along Lake Superior, while numerous areas of Huronian rocks were noted at the headwaters of the Gull river. The rocks of this latter series being schists and porphyroids.

Dr. Robert Bell of the Canadian Geological Survey calls the Keweenawan series of rocks the Nepigon series. This formation consists of the following rocks in ascending order, white grits, red and white sandstones, with conglomerate beds, the pebbles being mostly jasper in a sandy matrix of different colors: compact argillaceous limestones, shales, sandstones, and red indurated marls, red and white sandstones and red and white conglomerates, interstratified with diabase layers. These are covered by an enormous amount of trappean overflow crowning the formation, this overflow gives a singularly wild and weird aspect to the country; high, flat-topped hills or ridges, rising with sheer cliffs along the shores of Lake Nepigon and inland, making a strikingly odd landscape.

The rocks of the Animikie (which by the way means thunder, named after Thunder Bay district), are represented by (1)

greenish arenaceous conglomerates with pebbles of quartz, jasper and slate; (2) thinly bedded churts, mostly of a dark colour with argillaceous and dolomitic beds; (3) black and gray shales, with sandstone and ferruginous dolomitic bands, together with layers and intrusive masses of diabase.

I have named and classified these rocks rather fully, as they are of much importance in this district owing to the economic minerals associated with them.

Every one has heard of the Silver Islet mine near Thunder Cape. This mine is in the Animikie, together with a great many other mines that have been worked with considerable profit.

By far the greatest region I explored is covered with the Keweenawan series, but it is not so extensive as is shown on the geological maps of that region. And it is encroached on by the Laurentian from the west and also by a considerable area of Laurentian gneisses around Black Sturgeon lake. This formation yields lead, iron and copper. It is to the iron that I wish to refer more particularly. Two iron deposits were found in the Keweenawan region, one on the east side of Black Sturgeon lake, and another to the north-east of Dog lake. These deposits are large and consist of very good hematite. Undoubtedly with further prospecting more iron will be found. The iron appears close to the contact between the Laurentian and Keweenawan formations. Numerous lead and copper deposits have been found in this series of rocks, and as there is an extensive area of them in the district I explored, I am sure that new and valuable finds will be made when the country is opened up.

Evidently the Huronian areas travelled over are not barren, as I picked up a piece of pyrrhotite in this region that assayed 0.75% nickel and a trace of copper and silver.

Large deposits of beautiful marble are reported to be in the interior of this region, and samples have been brought out but I was unable to see them. Some of the sandstones and impure dolomites would make splendid building stone, while the whole world could be supplied with the very best road material in the shape of the tough fine grained traps that are found. A very peculiar thing in this formation is the occurrence of brine springs, which are

found in numerous places, the salt can be seen in the bottom of them in the shape of white grains. In former years the Indians used to get their supply of salt from these springs.

The chief question is what will this country be good for. I do not believe that more than twenty-five per cent. of the land is fit for cultivation, as the soil is too sandy and rocky, but there are patches of splendid land that could be cultivated. Good root crops could be grown and the hardy kinds of grain. The other seventy-five per cent. is taken up by lakes, rocky hills and muskeg, the latter affording a large amount of first class peat.

With the exception of a few patches of burn the whole country is covered with a healthy growth of timber. This district I believe was once a large white pinery but has been burnt over and replaced by other mixed conifers as the jack pine, spruce and balsam; evidences of this are to be seen all over the country in large scattered pine on the remains of dead ones. Unless nurseries are started as proposed by the forestry commission this country will never be a white pine country. As regards the spruce there is a tremendous quantity and this will be a great asset to the country; when we consider that "a cord of wood manufactured into cheap newspaper may be valued at $40, but would only be worth $7 sawed into lumber;" also the manufacturing of wood pulp and the sawing of lumber could be carried on in this district economically, owing to the water power to be found close at hand, providing that railway communication could be got. As regards the other timber, large tamarac is to be found in the district, this, next to rock elm and oak, makes the best boat building material. Unfortunately wooden boats are no longer built, but for piles and railroad ties and lumber this timber should be very valuable. Undoubtedly the jack pine will find a place as a marketable tree some day. At present it is represented as the most worthless tree we have got. Nevertheless it does make good pulp and railroad ties. So we are forced to look on this wood as of some value. Taking the district as a whole the timber represents the most valuable asset. At present, near the Canada Pacific Railroad, numerous pulp wood camps are operating, employing over six hundred men, the pulp wood being shipped to the United States and Canadian manufactories.

What Lake Nepigon and the Nepigon river is chiefly noted for is its wonderful speckled trout fishing; people travel for miles to enjoy a couple of weeks fishing on this beautiful river. Americans are forced to pay about $25 license for the privilege of fishing, while people in Ontario pay $5. During the summer months this river swarms with disciples of Isaac Walton, and the Indians derive a considerable income by acting as guides and canoemen.

As the pulp wood industry develops care should be taken that the fish in this river are protected and not killed out by the debris and rubbish which follows the using of a river for driving purposes and has caused so much harm to other rivers where fish were to be found. The protection of the fish in this lake and river should not be treated lightly, and strong efforts should be made to keep it clear and free from any filth that is likely to kill the fish. A larger income can be derived from selling licenses.

I have mentioned the prospects for mining development in this country, nothing definite can be said till further exploration is carried out.

Another asset to the country is the fur trade. At present the Hudson Bay Company with a few rival companies control the whole output. This region at one time was very rich in fur-bearing animals, but they are getting fewer in number and the trade is nothing as compared to twenty years ago. The caribou, moose and black bear are to be found, but are not plentiful. All the common animals are found, such as the beaver, mink, otter, etc.

The rivers in the district are rapid as a rule, with many falls, and as a number of them have a considerable volume and steadiness of flow, no great difficulty would be found in finding numerous places where power plants could be installed.

I have spent four summers in other parts of New Ontario, and have tried to observe carefully any natural resources that may come under my notice. Although I have seen better districts along the height of land farther east than this region, as regards timber, soil and game, yet taking it as a whole, I believe this country will prove of great value, not perhaps as a farming country, but rather as a lumbering, mining and game country. It will never be thickly populated, but still men will be able to derive wealth, if not great fortunes, by the development of its natural resources.

RATIO OF THE CYLINDERS OF A COMPOUND ENGINE AND WHAT TAKES PLACE IN THEM.

By Wm. Hemphill, Grad. S.P.S.

In taking up the subject of the compound engine or a steam engine of any kind, some authorities consider that practically everything is known about the engine, but I will endeavour to show that we have something to learn and prove about the expansion of steam and the ratio of the volumes of the h. p. and l. p. cylinders.

I will assume I have a compound engine before me all ready running, and I will first explain what takes place when the steam enters the cylinder and follow it throughout the stroke. For this I will not assume any given ratio between the volumes of the h. and l. p. cylinders, but that expansion takes place in each cylinder. For uniform action it would be better to have the engine running a short time, all parts being thus warmed up, so that cold metal will not interfere with any suppositions.

When the steam enters the h. p. cylinder from the steam chest it is at a certain pressure and the corresponding temperature; it may also be considered saturated. Just as the valve opens to allow the first portion of the steam to enter the h. p. cylinder, the cylinder and the piston are at a lower temperature than the entering steam, so some of the steam is immediately condensed, and this continues until the cylinder becomes the temperature of the entering steam, *i.e.*, the portion of the cylinder between the piston and the end of the cylinder that is open to the live steam. The piston is pushed forward to the point of cut-off and now the steam commences to expand and continues expanding until the point of release is reached. During this expansion the pressure of the steam decreases, consequently its temperature lowers; but the steam contained a certain amount of heat when it entered the cylinder, so if we had a perfect engine from which no heat could enter or escape, the heat liberated by the fall of temperature caused by

lower pressure, would be taken up in the steam which would be superheated during expansion, and the steam that was condensed at the first part of the stroke would be evaporated again, but as we have not an ideal engine to work with, we do not get such perfect results. The heat that is liberated by the fall of temperature is partly used in heating the cylinder walls as the piston moves out, exposing new portions of the walls to the steam, some of which heat may be used in re-evaporating the water caused by initial condensation. In fact this seems to be reasonable, for in working out tests we find as a rule a little more steam in the cylinder at release than at cut-off. Now release occurs and the steam is exhausted into a receiver or the l. p. steam chest. During exhaust the steam

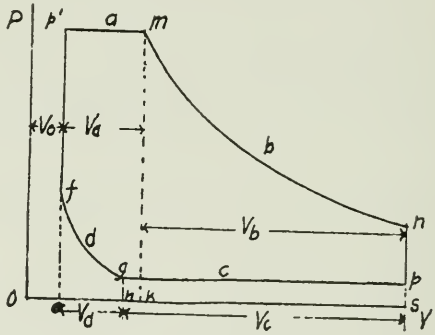


Fig. 1

is superheated owing to the large quantity of heat that is liberated by the drop in pressure. Then the l. p. cylinder takes the steam from the receiver and it is still further expanded until release occurs and the steam is exhausted into the condenser or air, according as the engine is condensing or non-condensing. Now with this rough idea of what takes place during the stroke, I will follow it out more particularly.

By following a method known as Hirn's Analysis we can determine the work done in thermal units for different parts of the stroke. In Fig. 1 the portions of the stroke are indicated by the subscript letters, thus a for admission, b for expansion, c for exhaust, d for compression. Then—

Va = volume in cu. ft. described by piston during admission.

Vb = volume in cu. ft. described by piston during expansion.

Vc = volume in cu. ft. described by piston during exhaust.

Vd = volume in cu. ft. described by piston during compression.

Vo = volume in cu. ft. of clearance space.

V = whole volume displaced by piston.

Let the work done in thermal units by the steam during the several portions of the stroke be represented by T with its appropriate subscript, thus—

Ta = work done during admission = area ep'mke in B. T. U.

Tb = work done during expansion = area Kmnsk in B. T. U.

Tc = work done during exhaust = area h g p s h in B. T. U.

Td = work done during compression = area e f g h e in B. T. U.

Ta + Tb = absolute work done by steam = area ep'muse.

(Ta + Tb)—(Tc + Ta) = net area of indicator diagram.

The quantities of heat in thermal units exchanged between the steam and the metal are represented by areas Ra, Rb, Rc, Rd, the areas being drawn to the same scale as the work diagram.

Ra = heat exchanged between metal and steam during adm.^{n}

Rb = heat exchanged between metal and steam during exp.^{n}

Rc = heat exchanged between metal and steam during exh.^{e}

Rd = heat exchanged between metal and steam during comp.^{n}

E = heat lost by external radiation.

Q = the quantity of heat supplied to cylinder per stroke by admission steam.

Q^1 = the quantity of heat supplied from jacket.

$Q + Q^1$ = total heat supplied.

Let M lbs. = weight of wet steam admitted per stroke, of which Mx is dry steam, and M (1—x) is weight of water present in steam. Let also the weight of steam retained in the clearance space each stroke = Mg. (The actual weight of this steam may be measured knowing the pressure g at beginning of compression.) Then the heat Q required to raise M lbs. of water from 32° F. to its temperature of admission, and to evaporate the portion Mx is $Q = M(h + xL)$ [h is sensible heat L = latent heat of steam].

For superheated steam heated from normal temperature tn of saturated steam to temperature ts—$Q = M\ [h + L + .48\ (ts - tn)]$.

The internal heat of the steam in clearance space at commencement of compression, assuming the steam dry=Mg (hg+lg).

Where Mg, hg, lg represent weight, sensible heat, and internal heat at pressure and volume at point g on the diagram Fig. 1.

The internal heat at cut-off $= (M + Mg)\ (hm + {}^{x}m\ \rho m)$, where ${}^{x}m$ = dry steam fraction on the diagram.

The internal heat at end of expansion—

$$= (M + Mg)\ (hn + {}^{x}n\ \rho m)$$

and similarly for the other points of the cycle.

Now to find the heat Ra. The heat supplied is Q, the heat in the cylinder at admission is—

$$Mf\ (hf + xf\ \rho f)$$

the work done is Ta; and the heat remaining in the steam at cut-off is $(M + Mg)\ (hm + xm\ \rho m)$. Then—

$Q + Mf\ (hf + xf\ \rho f = Ta + Ra + (M + Mg)\ (hm + xm\ \rho m)$.

from this can find Ra as all other quantities known.

To find Rb. The heat in the steam at the end of expansion is $(M + Mg)\ (hn + xn\ \rho n)$; the exteneral work is Tb, the heat present at beginning of expansion is $(M + Mg)\ (hm + xm\rho m)$. then—

$$(M + Mg)\ (hm + xm\ \rho m) = Tb + Rb + (M + Mg)\ (hn + xn\ \rho n).$$

from which Rb may be determined.

To find Rc. The heat in the steam at end of expansion is $(M + Mg)\ (hn + xn\ \rho n)$: the work done upon the steam during exhaust is Tc; the heat in the steam at beginning of compression, assuming the steam at compression dry: is $Mg + xg\ \rho g$).

To determine the heat rejected to the condenser must be done by a test of the engine, and weighing the steam condensed in a given time, and dividing this weight by the number of strokes made by the engine in that time. This will give the weight of steam M exhausted per stroke. Then M lbs. of steam become water at temperature t. The heat in this condensed steam is now Mht. The heat carried away by the condensing water equals the

weight of condensing water W per stroke multiplied by its increase of temperature in passing through the condenser = W $(t_1 - t_2)$. Then:—

$$(M + Mg)\ (hm + xn\ \rho n) + Te = Re + Mht + W\ (t_1 - t_2) + Mg\ (hg + xg\ \rho g\ .$$

from which Re may be obtained.

To find the heat Rd. The internal heat in the steam at beginning of compression is Mg $(hg + xg\ \rho g)$. Then work is done upon it = Td during compression; and the internal heat of the steam at end of compression is Mf $(hf + xf\ \rho f)$; then—

$$Mg\ (hg + xg\ \rho g) + Td = Mf\ (hf + xf\ \rho f) + Rd.$$

from which Rd may be found. This applies to one cylinder, by taking the other indicator card this may be applied to the l.p. cylinder.

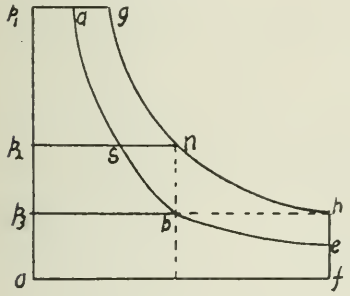


Fig. 2

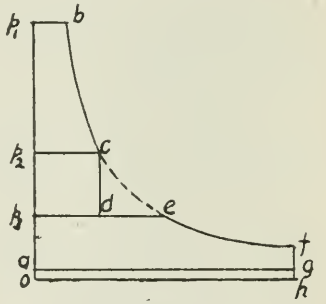


Fig. 3

We are now in a position to follow the diagram of Figs. 2 and 3, and follow the action in the cylinder on other lines than heat units.

To do this it will be more satisfactory to assume some definite proportions, let the ratios of the cylinders be 1:2; the cut-off in the l.p. cylinder to be constant at .5 of stroke and to enclose a volume at cut-off equal to the volume of the h.p. cylinder. Then the distribution of power between the cylinders may be shown by Fig. 2, in which I assumed hyperbolic expansion. In practice this diagram would be subject to a number of changes, but it illustrates in a very satisfactory way various results in a compound engine.

Take cut-off at .25 of the stroke in the h.p. cylinder and at an initial pressure p, shown on Fig. 2, the steam expands along a b until it reaches the pressure $p_3 = p_1 \times .25$ neglecting clearance (this is also the pressure in the receiver). The work diagram of the h.p. cylinder equals area p_1 abp_3, and of the 1.p. cylinder the area p_3 befo, point b being the cut-off in the 1.p. cylinder.

Suppose now we make the cut-off in the h. p. cylinder at .5 of stroke, then nearly twice the weight of steam is supplied per stroke, and the steam at release is at a higher pressure than when cut-off occurred earlier. Call this pressure p_2 as shown on Fig. 2, and the pressure of the receiver, p_2, is the back pressure on the h.p. piston and the forward pressure on the 1.p. piston to the point of cut-off at n now, and the work diagram is now given by the areas p_1 gnp_2 and p_2 nhfo by the small and large cylinders respectively. A glance at fig. 2 shows the difference in the work by changing the point of cut-off in the h.p. cylinder; it shows a marked increase in work for the 1.p. piston, while the h.p. work is practically the same.

Thus we find to increase the power of the engine we have to increase the per cent. of cut-off, but the larger share of the increased power comes from the 1 p. cylinder; while with early cut-off and low power the larger share of the work comes from the h.p. cylinder. And as this power can be decreased to a minimum, the power of the 1.p. cylinder may be reduced to zero.

Now consider the effect of throttling the steam supply with the same ratio of cylinders, and cut-off fixed in both cases at .5 of stroke without "drop." The initial pressure was p_1 before and let it be throttled to $p_2 = \frac{1}{2}p_1$. Then in fig. 2, the distribution of work is seen as area p_2 sbp_3 for the h.p. cylinder and p_3 befo for the 1.p. cylinder. This shows the work area for the 1.p. cylinder the same for steam throttled as with high pressure, with cut-off at .25 of stroke, but the work area in the h.p. cylinder is much less, when the steam is throttled, giving a less satisfactory distribution of power between the cylinders for throttling than having cut-off earlier. It shows that theoretically, throttling to a pressure p_2 is less economical than changing the cut-off from .5 to .25 with constant initial pressure, for in both cases the same weight of steam

is exhausted per stroke, *i.e.*, the 1.p. cylinder volume at pressure f e, though with throttling the useful work area is reduced by the area p_1 asp$_2$. This theoretical gain would not all be realized in the actual case owing to cylinder condensation with an early cut-off.

Another way of remedying the unequal distribution of power between the cylinders is by having a variable cut-off in the 1.p. cylinder. Let us take the cylinder ratios 1:4 and cut-off in each cylinder at half stroke, and let p_1 bcdp$_3$ fig. 3, be the work area of the h.p. and p_3 efga the work area for the 1.p. cylinder. Now change the cut-off in the 1.p. from .5 to .25 of the stroke; then the work areas will be changed, the h.p. being p_1 bcp$_2$ and the 1.p., p_2 efga. Conversely if the cut-off in the 1.p. be made later then the work area in the h.p. will be increased, and decreased in the 1.p. cylinder.

In the above methods the effect of the receiver between the cylinders was not taken into account. In the majority of compound engines a receiver is placed between the cylinders to receive the exhaust steam from the h.p. cylinder and to give it to the 1.p. cylinder. This receiver often takes the form of a pipe and the valve chest. (The above has reference to a cross-compound engine.)

Now if this area were indefinitely large, the back pressure line of the h.p. and the forward pressure of the 1.p. cylinder, would be each a horizontal straight line. In practice the receiver volume is from $1\frac{1}{2}$ to several times the volume of the h.p. cylinder. The effect of the restricted volume of the receiver is to make the back pressure line of the high and the admission line of the low-pressure diagram irregular.

The receiver volume is made as small as possible to avoid radiation of heat, but space is an important factor to consider in the size of the receiver. The effect of a small receiver is to increase the small cylinder's back pressure and to increase the initial pressure of the large cylinder. Sometimes an increase in pressure occurs in the 1.p. cylinder towards the point of cut-off, which is caused by the h.p. cylinder's exhaust passing into the receiver before cut-off has taken place in the low.

In designing an engine it is usual to get the diameter of the 1.p. cylinder first, and then the diameter of the h.p. cylinder depends on a number of conditions, but the main object is to have the power evenly divided between the two cylinders. After looking through a number of catalogues, I find the ratio of the volumes of the cylinders range from 1:2½, 1:3, and 1:4, rarely higher, or the diameter of the 1.p. cylinder is twice that of the h.p. cylinder minus two. Nearly all the manufacturers cling to this idea of ratios, which later on I will endeavor to show is an error in the point of economy in the engine.

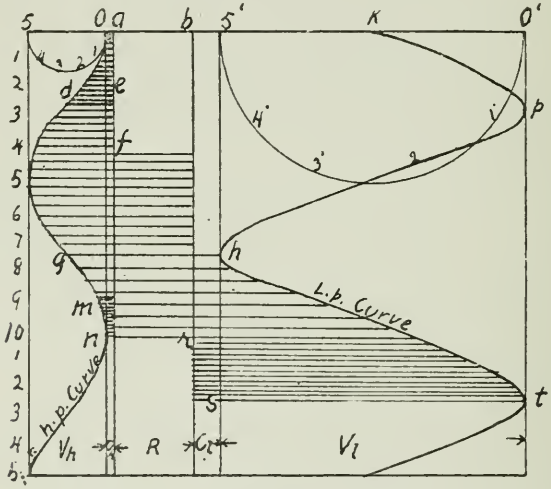


Fig. 4

Let us now construct a diagram which will show the piston displacement in a compound-engine. To do this it is necessary to assume ratios of cylinders, clearance and receiver volumes for a given compound-engine. By this diagram it will be possible to follow the steam through the engine, and it illustrates the changes of volume and pressure between the points of entering and leaving the cylinder.

In fig. 4, horizontal lines are lines of volume, and vertical lines are divided into portions of a revolution. Then let aO = volume of h.p. clearance (Ch); O5 = volume of h.p. piston displacement (Vr); ab = volume of receiver (R); b5' = volume of

l.p. clearance (Cl); and 5′O′ = volume of l.p. piston displacement (Vl).

On the lines O5 and O′5′ draw semicircles representing half a revolution of the crank-pin and divide it into any number of equal parts, say five. On the vertical line to the left of fig. 4, set off ten equal parts representing parts of a revolution. The diagram shown is for one and a half revolutions. The cranks are assumed at right angles, when the h.p. piston is at beginning of stroke O and the l.p. piston is at centre of stroke K. Through the points on the vertical line numbered 1, 2, 3, etc., draw horizontal lines, let these intersect the vertical lines drawn through the numbers on the semicircle, the intersection of these lines for the corresponding number gives a point on the "curve of piston displacement." Obtain a number of these points for both cylinders and the curves can be swept in as shown. The different grades of hatching show the volumes in the cylinder as admission to h.p. cylinder, expansion in h.p. cylinder, etc. It is easily seen from the figure all these points and also the connection between the two cylinders. The h.p. clearance Oa is first filled with steam at initial pressure, and the steam is continued to the point of cut-off at half stroke, and volume in cylinder = de. The steam is then expanded to nearly the end of the stroke, when the exhaust port opens, and at f the steam passes into the receiver. Now the exhaust side of the h.p. cylinder and the receiver are in communication, as shown, until the l.p. steam port opens at h. Here the volume of the steam = gh. At m the h.p. exhaust port is closed, and compression begins. At the point r in the l.p. piston cut-off takes place and the steam expands to volume st. This diagram can be applied to the indicator diagrams of compound engines as shown fig. 5.

This figure shows the piston displacement curves for cranks at right angles, the theoretical indicator diagram of the h.p. cylinder being drawn below the h.p. piston curve, and the l.p. indicator diagram below the l.p. curve. The initial pressure is known, and is set up from the zero line of pressure. In the diagram cut-off occurs at .4 of stroke in the h.p. cylinder, and as the initial pv is known, all other points in the cycle may be determined, assum-

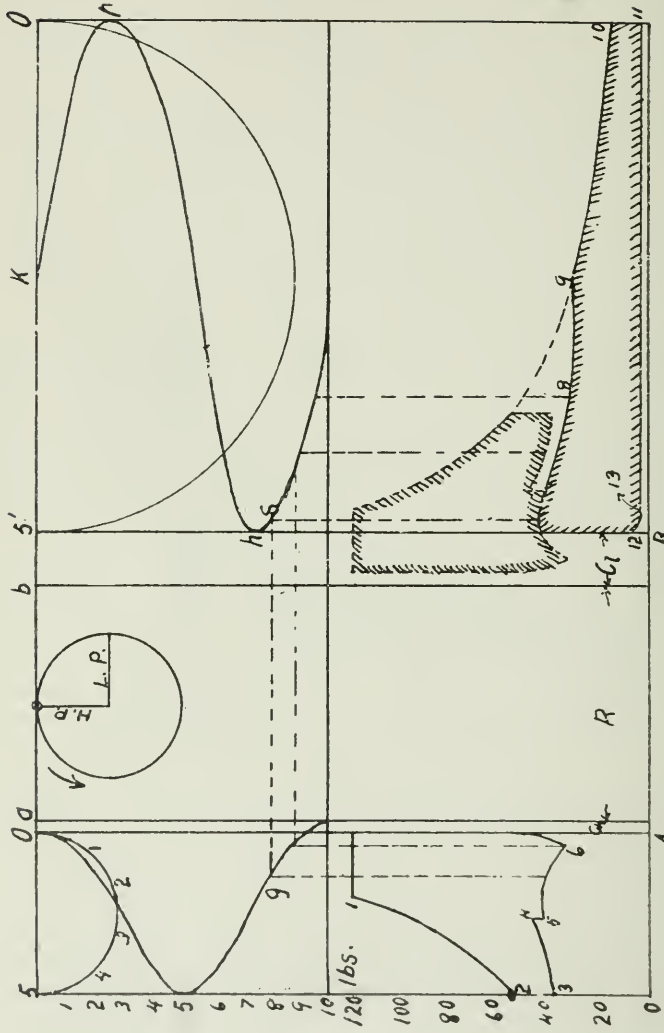


Fig. 5

ing hyperbolic expansion. In the following equations the subscripts refer to the figures on the portions of the diagram representing the theoretical indicator diagram. Thus V_3 = volume of steam at point 3, measured from beginning of stroke, *i.e.*, from vertical line Oa and to the left in the h.p. diagram, and from vertical line through B and to the right in the l.p. diagram. When the exhaust side of the h.p. cylinder is in communication with the l.p. cylinder, then the volume including that of the receiver, is given by the horizontal intercept between the lines of piston displacement.

For this diagram it may be assumed that pv = a constant, then:—

$$p_1 (v_1 + Ch) = p_{10} + Cl),$$

from which the terminal pressure is obtained, and the point of cut-off in the l.p. cylinder being known, then—

$$p_9 (v_9 + Cl) = p_{10} (v_{10} + Cl),$$

from which p_9 or the pressure at cut-off in the l.p. cylinder, and therefore the pressure in the receiver at that time is known.

Then the pressures at all other points may be obtained by the following equations:—

Referring to the theoretical diagrams in the lower part of fig. 5, then for the h.p. cylinder

$$p_1 (v_1 + Ch) = p_2 (v_2 + Ch).$$

At point 2 the steam exhausts and mixes with that in the receiver, which is at some pressure p_9 previously calculated.

$$p_2 (v_2 + Ch) + p_9 R = p_3 (v_3 + Ch + R).$$

But during the return of the h.p. piston, so long as the l.p. cylinder is not open to receive steam, the volume enclosed is for the moment reduced, hence the pressure rises to p_4 until the l.p. valve opens the port to steam, when the pressure instantly falls to p_5, then—

$$p_3 (v_3 + Ch + R) = p_4 (v_4 + Ch + R).$$

When the l.p. valve opens to steam, the receiver steam mixes with that in the clearance space of the l.p. cylinder; thus—

$$p_4 (v_4 + Ch + R) + p_{12} Cl = p_5 (v_5 + Ch + R + Cl).$$

This action continues, and meanwhile the l.p. piston is moving forward and increases the displacement, causing the pressure

to fall to p_6, when the h.p. exhaust valve closes, and compression begins in the h.p. cylinder; then—

$$p_5 (v_5 + Ch + R + Cl) = p_6 (v_6 + Ch + R + Cl + v_8).$$

where v_8 is the volume displaced by the l.p. piston from the beginning of its stroke, and which volume may be measured by the horizontal intercepted between the lines of piston displacement, as shown by the dotted projectors. The back pressure p_{11} in the l.p. cylinder is fixed—

$$(p_{12} \ Cl) = p_{11} (v_{13} + Cl).$$

The same principles may be further extended to represent changes in any number of cylinders taking two at a time. In fig. 5 the h.p. diagram is shown dotted over the l.p. diagram to show more clearly the relation between them.

In what I have said so far on the compound-engine it was not necessary to take into account the ratios of the volume of the h. and l.p. cylinder; all the assumptions that were made were very limited, as I only wanted to show what took place in the cylinders, to follow the steam through the stroke, illustrating it by diagrams, and also how the work was divided up, giving the latter in heat units as well as work units. It is now my intention of dealing with the ratios of the volumes of the cylinders, and endeavor to show that it is an error in assuming that everything is now authoritatively settled about the design of the steam engine which seems to be the prevailing idea in the minds of those who write text-books on thermodynamics and heat engines, although in a general way this idea may be accepted as true, for the steam engine of James Watt considered as an automatic mechanism was not different in any essential particular to what we have to-day. The fact of cylinder condensation was known then although not understood to the extent that it is to-day.

A great many compound corliss and marine engines have been built in the last twenty or thirty years, but only in the last eight or ten years has anything been known experimentally of the most economical volumes of cylinder ratios. We see, as I mentioned before, that in Europe and America the ratios run from 1:4. The reason of this is the fact that an engine so proportioned avoids more than a very slight "drop" in pressure from that at the end

of expansion in the smaller cylinder to the pressure at cut-off in the large cylinder, with reasonable ratios of expansion in each. When "drop" occurs it is because free expansion takes place, caused by the sudden enlargement of the volume of the steam without doing work against a piston. As this "drop" is not reversible in the idea of a cycle it is considered loss. Since the time of Watt's invention the steam pressure has been increasing, but no change has been made in the ratios of the cylinders. So far as I can learn Carl Busley, Professor at the German Imperial Academy at Kiel, is the only authority who would change the ratios of the cylinders in compound engines for different steam pressures. He gives the following ratios:—

Pounds per sq. in.	60	90	105	120
Ratio	1:3	1:4	1:4.5	1:5

Professor Ewing is very positive in his statement that care should be taken not to allow free expansion into the receiver as "drop" occurs which would be shown on an indicator diagram by a sudden fall at the end of the h.p. expansion. All these statements about "drop" being wasteful were assumed, no one taking the trouble to perform experiments to prove the supposition. It is true that "drop" is wasteful, but I think the effect of allowing this "drop" can be utilized to make "drop" a gain in the end. The "drop" I refer to must not be mistaken for the drop caused by sudden radiation or condensation, but that resulting from intermediate expansion, although it looks as if authorities put the two together under the same head. In D. K. Clark's Rules, the following discussion occurs on the influence of "drop."

"That the work of expanding steam is to be calculated from the expansion upon a moving piston only is obvious enough when it is considered that the steam may expand into an intermediate receiver, and into intermediate passages, without doing any work on a piston, whilst at the same time the pressure falls or drops as the volume is enlarged. Under these circumstances the second cylinder receives the steam at a lower pressure and in larger volume than it has when there is no intermediate expansion and fall of pressure, and there is less work done, whilst the ratio of active expansion is necessarily reduced. If the second cylinder, however,

be enlarged in capacity in proportion to the enlargement of the volume of steam and the fall of the pressure by intermediate expansion, the ratio of expansion and the work done in it would remain the same." These quotations considered by themselves would commit Clark to the common belief that "drop" produced by intermediate expansion causes a serious waste. He goes a little farther in the right direction than others have done, however, in the suggestion that the waste occasioned by "drop" may be balanced by enlarging the second cylinder; but he does not, in this immediate connection, draw attention to the fact that the loss in pressure of the receiver steam, due to the practice of taking more steam by volume from the receiver than it gets from the h.p. cylinder is accompanied by an increase of work in the h.p. cylinder. By this the back pressure in this cylinder is reduced and at the same time the initial pressure in the l.p. cylinder. Therefore the loss occasioned by receiver expansion is much less than Clark implies in his quotation, and if high boiler pressures are used with a moderate amount of "drop" this loss, even from a thermodynamical point of view is quite insignificant. Let us now consider the causes of "drop" and the advantages that accompany its moderate use.

There are two causes of "drop." The first is intermediate expansion. When more steam by volume leaves the receiver than is put into it per stroke (assuming no steam made or condensed in the receiver), the receiver pressure must be less than the pressure in the h.p. cylinder at release. The other cause of "drop" is cylinder condensation and clearance in the l.p. cylinder. If a receiver compound engine had neither clearance or condensation in the l.p. cylinder, there might still be any amount of "drop" if the cut-off on that cylinder were lengthened enough. Again, if the cut-off were adjusted just right to prevent any "drop" in such an engine, and the cylinder had the usual amount of clearance and condensation, a "drop" of from 12 to 15 pounds might result. Even this could be prevented by making the cut-off earlier in the stroke. Therefore it is seen that cut-off may be a cause or a corrective of "drop." But the point of cut-off is dependent on considerations other than its effect on drop. It would be desirable

to have the cut-off occur late in the stroke were it not for the loss of excessive free expansion, as this would reduce the range of temperature of the l.p. cylinder walls, and would, therefore, reduce the loss from initial condensation in this cylinder.

It is easily seen from the foregoing that unless the best point of cut-off, chosen with reference to the waste by initial condensation happens to coincide with that particular point at which "drop" would be entirely prevented, a compromise must be made between the gain by lengthening cut-off and the loss by free expansion. This does not have to be done in cylinder ratios of 1:3, but it is necessary for larger ratios as 1:6 or 1:7. If "drop" is accompanied by a reduction of initial condensation in the large cylinder, in amount sufficient to overbalance the waste of power by intermediate expansion, it is at least, no detriment to the coal consumption to allow that much "drop." This "drop" is considered very useful in plants driving a varied load, as it allows a widely variable cut-off in the second cylinder without either looping at the end of expansion in the first cylinder or materially changing the receiver pressure.

After dealing at some length with intermediate expansion it would be well to consider some of the general theory of the compound engine. We will assume the proposition that the highest economy to be obtained in an engine of any type is the result of two conditions—using a volume of steam at the highest possible pressure and expanding it the greatest number of times. But we find both the pressure and expansions are limited by practical circumstances; the pressure by the increase in cost of boilers and piping, while the ratio of expansion, by the increase in waste due to cylinder condensation, friction and repairs. All the authorities appear to agree that there is a minimum number of expansions allowable in each cylinder. This number is between four and five. But in an engine with cylinder ratio 1:3, practically no "drop" will occur, and custom has limited the number of expansions for such an engine to 12 or possibly 15. A steam pressure of 115 pounds for such an engine gives the best result as to economy. A higher pressure would enable the engine to do more work, but the number of expansions remaining the same the steam

consumption would not be affected. Now if higher pressures are going to be used with the idea of improving the economy, it would be necessary to add another cylinder so that increased expansion could take place. The average pressure for triple expansion engines is from 150 to 160, and even higher; but with the usual ratio of cylinders—1:2.75 :6.5—the number of expansions in each cylinder would be much less than that given above. The reason of this is that 150 pounds pressure is not enough to permit the larger number without developing too little pressure at release in the 1.p. cylinder.

Now in the triple expansion engine we have increased the engines from two to three, as a compound engine really consists of two engines, each requiring the same number of parts and the same equipment all through. To this we have added the third which will increase the cost of the engine, an important item in the majority of cases. The volume of steam in the h.p. cylinder is expanded from that volume to the volume of the 1.p. cylinder; it is not done direct but through the intermediate cylinder, but amounts to the same thing in the end. Now for mill engines and all stationary plants I think that this increased expansion could take place in the two cylinders instead of three. In fact I find for stationary work the compound engine is preferred to the triple expansion engine. Now I think if the ratio of the cylinders in the compound engine were increased to 1:7 or 1:8, and perhaps even greater for mill work, or any stationary work, the economy in fuel would be nearly if not quite equal to the triple expansion engine. The only way to prove this is to perform a number of tests on each kind of engine, *i.e.*, the triple expansion and a compound engine of different cylinder ratios, some large and some small. I do not say that the compound engine, with large ratios, will prove the more economical with regard to fuel and water supply, but if the pressures in each case are, say 180, it will hold a very high place.

I will now give a few results of some tests with regard to fuel and water, that have been obtained by competent men on compound engines using the ordinary ratio of the volume of cylinders. One of the large ratio I have considered above, also a triple

expansion engine. The results will speak for themselves, and I think the large ratio for compound engines will soon be taken up more favorably, and will take the place entirely of the triple expansion engine, although I think, in marine work, the triple expansion engine should be retained, if only for mechanical reasons. So far as I can learn I think there have been only a few of these engines made with the large ratio for the cylinders. These were made by the American Wheelock Engine Company, and all but two surpassed the makers guarantee for fuel and water supply.

Test 1.

Kind of engine—Cross-compound Wheelock engine, made by Goldie & McCulloch, Galt, Ont.

Ratios of cylinder, volumes 1:3.4.

Steam pressure, lbs. 82.5.

I. H. P. 239.

Coal per I. H. P. hr. 1.9.

Water per I. H. P. per hr. 17.2 lbs.

Test 2.

Kind of engine—Tandem-compound, four valve type, made by Russel Engine Co., Massillon.

Ratios of cylinder volumes 1:4.3.

Steam pressure 160 lbs.

I. H. P. each engine 300.

Coal per I. H. P. per hr. 2.55 lbs.

Water per I. H. P. per hr. 15 lbs.

Test 3.

Kind of engine—Cross-compound, made by American Wheelock Engine Co.

Ratios of cylinder volumes 1:7.2.

Steam pressure 140 lbs.

Cut-off h.p., .287 of stroke; l.p., .236 of stroke.

I. H. P. 650.

Coal per I. H. P. per hr. 1.18 lbs.

Water per I. H. P. per hr. 11.89 lbs.

Test 4.

Kind of engine—Allis triple expansion pumping engine.

Ratios of cylinder volumes 1:2$\frac{3}{4}$:4$\frac{1}{2}$.

Steam pressure 185 lbs.

I. H. P. 750.
Coal per I. H. P. per hr. 1.02 lbs.
Water per I. H. P. per hr. 10.48 lbs.

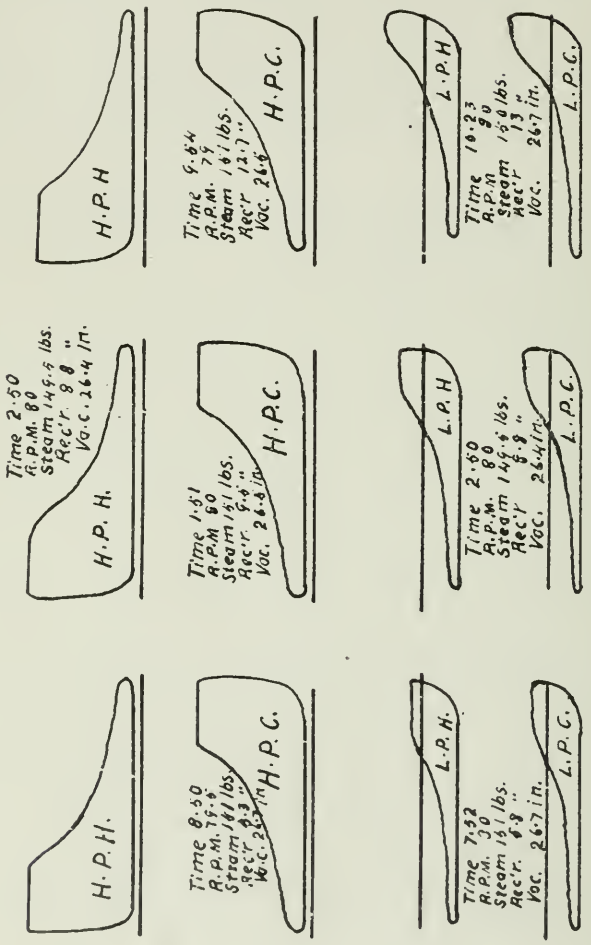


Fig. 6

Fig. 6 is a copy of some indicator cards taken from the engine while Test 3 was going on. The cards are very good and there is nothing to indicate in the l.p. cards that the increased volume is detrimental.

THOMSON RECORDING WATTMETER.

C. G. Carmichael, '01.

While comparisons between the meter and contract systems are no longer necessary, the choice of a meter is an important consideration: Shall it be an ampere meter registering the current, or a wattmeter registering the energy? To answer this let us examine effects of voltage on a 16 candle power, 3.1 watt incandescent lamp. A variation in voltage of 3% from normal is quite common, but the 2% variation given in Table 1, is quite sufficient for our purpose.

Table 1.—Effects of voltage on a 16 C. P., 3.1 watt incandescent lamp. Normal voltage 100.

Volts.	Candle p'w'r	Watts per Candle	Amperes	Total Watts
98	14·40	3·33	0·485	47·5
99	15·20	3·21	0·492	48·8
100	16·00	3·10	0·496	49·6
101	16·96	3 00	0·504	50·8
102	17·92	2·91	0·512	52·2

Suppose the Electric Light Co. is able to dispose of its power at the low rate of 10 cents per kilowatt hour. From Table 1, we see that a 16 C. P., 3.1 watt lamp at normal voltage takes 0.496 amperes. Since an ampere meter is calibrated from an indicating wattmeter, the voltage being kept constant at normal for this case a rate of 10 cents per K. W. H. is same as 1 cent per ampere hour. Also here a rate of 10 cents per K. W. H. is same as 0.031 cents per candle power hour.

We can now deduce the following table of charges per lamp hour, according to above three methods.

Table 2.—Charge per lamp hour.

Voltage	Charge per lamp hour at 10 cents per K. W. H.	Charge per lamp hour at 1c per ampere hour.	Charge per lamp hour at 0·031c. per candle pow'r hour.
98	0·4751c	0·485c	0·4464c
99	0·4880	0·492	0·4712
100	0·4960	0·496	0·4960
101	0·5088	0·504	0·5258
102	0·5220	0·512	0·5555

It can thus be seen that when voltage is below normal the ampere meter records more power than is used, and when voltage is above normal this same meter records less power than is actually consumed. Apparently it might therefore be argued that it would pay to use ampere meters and keep the voltage low. But any Electric Light Co. could soon tell you how many customers it would have at the end of a year were it to supply only 14 C. P. and charge for 16 C. P.

Now consider the customer. He wants so much light. Virtually he wants to pay so much per candle power hour. Say he is a merchant and in a year he uses 200 sixteen candle power lamps for 500 hours or 100,000 lamp hours. From Table 2, his lighting bill is found.

For a voltage of 98—

By Wattmeter his bill would be $475.10
By Ampere Meter his bill would be 485.00
His just bill at 0.031 cents per C. P. hour is 446.40

That is Ampere Meter charges him too much by $38.60, and Wattmeter too much by $28.70, that is Wattmeter is more nearly correct by $9.90.

For a voltage of 102—

By Wattmeter his bill would be $522.00
By Ampere Meter his bill would be 512.00
And his just bill at 0.031 cents per C. P. hour is. 555.50

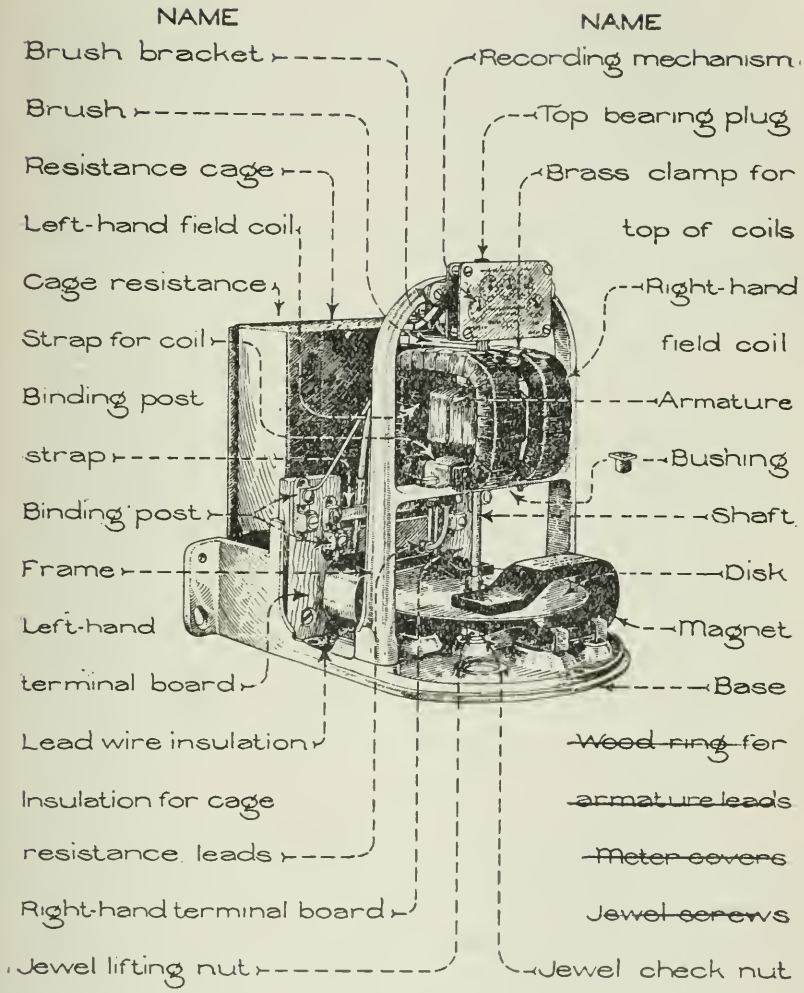

NAME
Brush bracket
Brush
Resistance cage
Left-hand field coil
Cage resistance
Strap for coil
Binding post strap
Binding post
Frame
Left-hand terminal board
Lead wire insulation
Insulation for cage resistance leads
Right-hand terminal board
Jewel lifting nut
NAME
Recording mechanism
Top bearing plug
Brass clamp for top of coils
Right-hand field coil
Armature
Bushing
Shaft
Disk
Magnet
Base
~~Wood ring~~ for ~~armature leads~~
~~Meter covers~~
Jewel screws
Jewel check nut

FIG. 1.

That is by registration of current the merchant is charged too little by $43.50, and by registration of energy too little by $33.50, again showing a difference, of $10.00, in favour of the Wattmeter.

The first requirement essential to a perfect recording meter is therefore registration of energy and not current, one of its factors. A meter must be, simple and durable; able to resist tampering and independent of atmospheric conditions; independent of frequency and inductive circuits and must be adaptable to either direct or alternating current.

I will attempt a brief description of the Thomson Recording Wattmeter. In Fig. 1 is shown a 5 ampere, 220 volt meter, the connections being shown in Fig. 2.

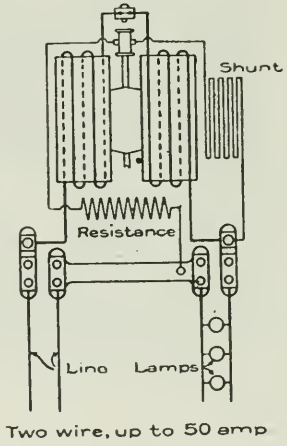


Fig. 2.

It is simply a small motor and dynamo combined. A small fraction of the energy which the meter measures operates the motor, and the retardation is supplied by the light drag of a copper disk rotating between the poles of two magnets.

The armature consists of a number of coils of fine wire wound upon a frame of pressed paper, which is fastened to the vertical shaft. The commutator bars are made of silver and the brushes are tipped with that metal. The armature, in series with a suitable resistance and the shunt, is connected across the line. The fields consist of a number of turns of stout copper wire of size

sufficient to carry a current of twice the rated capacity of the meter. These fields are connected in series with one side of the line the full current passing through them. Hence the torque of the motor is exactly proportional to the watts.

There is no iron about the motor, and the meter when once calibrated is adaptable to either direct or alternating current. In fact were we to replace the brushes by two connections affixed to opposite segments in the commutator and attaching a suitable spring and pointer to the shaft, we would have an indicating wattmeter capable of being used on any circuit.

The copper disk rotates between the poles of two magnets. By moving the magnets out or in the speed is regulated so that the number of revolutions of the disk in a certain time corresponds to energy delivered to the circuit in that time. On the shaft is a worm which operates the recording mechanism.

As before stated the shunt is connected in series with the armature and resistance across the line. It consists of a suitable number of turns of fine wire and is inserted in the inside of one of the field coils. Its object is to assist meter on light loads, thus giving the meter great accuracy on all loads.

In the lower end of the shaft is a polished, hardened steel detachable pivot. The shaft sits on a jewel mounted on a spring in the end of a screw. So that if from any cause jewel or pivot should be damaged both can be easily removed and replaced by new ones without removing the cover. The meter is protected by a metallic cover which is drawn tightly down on to a strip of felt on the base, thus rendering it dust proof. To the underside of the base is fastened a metallic plate, when it is sealed up it is impossible to tamper with the meter without breaking the seals.

Wattmeters are tested by connecting them up with an indicating Wattmeter: and with a stop watch noting the time of a certain number of revolutions of the disk. The formula,

$$\frac{3{,}600 \times \text{constant} \times \text{number of revolutions}}{\text{time (in seconds.)}}$$

gives watts recorded by the recording meter and this should agree with the reading of the indicating wattmeter. If there is not a

close enough agreement the magnets are moved out or in, according as meter is fast or slow.

The formula is derived as follows:

Let 1 revolution of disk in 1 hour = 1 watt hour.

Hence 1 revolution of disk in 1 sec. = 3,600 watt hours.

Or N revolutions of disk in 1 sec. = 3,600 × N watt hours.

Or N revolutions of disk in t sec. $= \frac{3{,}600 \times N}{t}$ watt hours.

Now suppose we took a 25 amp., 100 volt meter and passed 100 amperes at 100 volts. through it, the disk would rotate at the abnormal speed of 166.68 R. P. M. If the field coils were made with one-quarter of the number of turns of wire the torque, and hence the speed of the disk would be one-quarter of what they were before. Since the disk is running at one-quarter of the speed necessary to record the power in the circuit, the dial will indicate only one-quarter of the power, so the dial reading is multiplied by 4, or as it is termed "constant 4." Then formula becomes

$$\frac{3{,}600 \times \text{constant} \times \text{number of revolutions}}{\text{time (in seconds)}}.$$

Another way of looking at it is—

Let W = watt hours.

N = number of revolutions.

t = time in seconds.

K = constant.

$W \propto 3{,}000\frac{N}{t}$

W ∝ Revolutions per hour.

$W = K\frac{3{,}600N}{t}$

By choosing the proper value for $\frac{3{,}600N}{t}$ we can have any value of K, ½, 1, 2, etc., depending on the size of the meter.

Everything should be carefully considered before selecting the proper size of wattmeter to be used. If a building is to be illuminated with 400 lamps it does not of necessity follow that a 400 light meter will do. Take the case of a theatre using 300 sixteen candle power lamps. Probably ten of the lights would be

used a greater portion of the day to light up the ticket office, lobby, etc., and remaining 290 would only be used a short time during a performance. Now I would place a ten light meter on the first mentioned circuit, and a two hundred light meter on the lights in the main part of the theatre. It is far better to have too small a meter on an intermittent load than too large a one.

Heretofore it seems to have been the practice, especially in regard to house lighting, to locate the meter in the most undesirable spot possible. Garrets and cellars are favorite spots. In the former there is a 120° range of temperature between winter and summer, while in the latter it is usually damp. Is it not unreasonable to expect good results from meters located in such places? A good location is any of the back living rooms in the house.

When a meter is set up it should be examined annually by a competent person. Don't suppose that it is going to run forever after it has first been inspected and sealed up. In fact, the successful use of wattmeters depends largely upon the intelligence with which they are looked after.

PORTLAND CEMENT vs. BONE ASH FOR CUPELS.

H. Roy Stovel.

The use of bone ash for cupels is so universal, that it is with great diffidence one seeks to introduce any other substance in place of it.

Portland cement on first thoughts does not recommend itself to one for this purpose, on account of its hardness when set. Through having had it suggested to me in a chance conversation I concluded to give it a trial, and have had most satisfactory results, finding it equal to and if anything slightly better than bone ash in every way.

The cement cupels being much harder and stronger, will admit of any kind of handling both in and out of the furnace. They can be dropped or even thrown down without any material damage. Neither are they so liable to fracture in the furnace as are the bone ash ones. In twenty experiments I have only found one with a crack in the cup, and that one so small that it was impossible for any bead but a very minute one to fall into it.

The cement being slightly heavier than bone ash with equal absorbing powers, it follows that size for size the cement cupels will absorb more lead, while for ordinary size buttons they may be made shallower, thus enabling one to see more of the cup while in a small muffle, and at the same time a saving is made in material.

As will be seen in the accompanying table the loss with the cement cupels is, in most cases, slightly less than with the bone ash ones, varying for 18 cupellations, of from 2 to 600 mgs. of silver, from nothing to 4.86%.

The relative cost of the two materials, locally, is much in favour of the cement, bone ash costing by bulk 7 cents per lb. while the price of cement is $6.50 at Yellow Union per bbl., being only a fraction of the price of the bone ash.

PORTLAND CEMENT vs. BONE ASH CUPELS.

Results Obtained in Comparative Experiments.

No.	Kind of Cupel.	Weight of Silver.	Time put in F.	Time to clear	Time Finished.	Weight after Cupellation.	Loss in wt.	% Loss.	Time in F.	REMARKS.
1	Bone Ash	$104\frac{27}{60}$ mg	3 – 22	2′	3 – 38	$102\frac{27}{60}$	2 mg	1.91	16′	Result in favour of Bone Ash Cupel.
2	Portland Cem.	$101\frac{15}{60}$ mg	3 – 22	$1\frac{1}{2}$′	3 – 45	100	$2\frac{2}{60}$ mg	1.98	23′	
3	Bone Ash	$591\frac{24}{60}$ mg	3 – 45	4′	4 – 13	581	$10\frac{24}{60}$ mg	1.75	28′	Result in favour of Portland Cement.
4	Portland Cem.	$599\frac{58}{60}$ mg	3 – 45	$4\frac{1}{2}$′	4 – $13\frac{1}{2}$	$588\frac{38}{60}$	$9\frac{20}{60}$ mg	1.56	29′	
5	" "	2 mg	1 – 45	6′	2 – 17	2	.....	.....	32′	Cupelled with 20 gms. lead.
6	Bone Ash	$2\frac{4}{60}$ mg	1 – 45	6′	2 – 18	$2\frac{4}{60}$	.....	.....	33′	" " " "
7	" "	$3\frac{39}{60}$ mg	1 – 45	6′	2 – 18	$3\frac{39}{60}$	.....	.....	33′	" " " "
8	Portland Cem.	$3\frac{42}{60}$ mg	1 – 45	8′	2 – $19\frac{1}{2}$	$3\frac{42}{60}$	.....	.....	$34\frac{1}{2}$′	" " " "
9	" "	$8\frac{42}{60}$ mg	1 – 45	7′	2 – 19	$8\frac{26}{60}$	$\frac{16}{60}$ mg	3.06	34′	" " " "
10	Bone Ash	$8\frac{42}{60}$ mg	1 – 45	12′	2 – 21	$8\frac{26}{60}$	$\frac{16}{60}$	3.06	36′	" " " "
11	" "	$13\frac{24}{60}$ mg	1 – 45	13′	2 – 21	$13\frac{18}{60}$	$\frac{6}{60}$	.74	36′	" " " "
12	Portland Cem.	$13\frac{22}{60}$ mg	1 – 45	13′	2 – 22	13	$\frac{22}{60}$	2.74	37′	" " " "
13	Bone Ash	17 mg	2 – 25	3′	3 – 21	$16\frac{14}{60}$	$\frac{46}{60}$	4.53	56′	" " " "
14	Portland Cem.	$16\frac{58}{60}$ mg	2 – 25	3′	3 – $01\frac{1}{2}$	$16\frac{4}{60}$	$\frac{46}{60}$	4.50	$36\frac{1}{2}$′	" " " "
15	Bone Ash	$9\frac{27}{60}$ mg	2 – 25	2′	3 – $01\frac{1}{2}$	9	$\frac{27}{60}$	4.76	$36\frac{1}{2}$′	" " " "
16	Portland Cem.	$9\frac{31}{60}$ mg	2 – 25	2′	3 – $01\frac{1}{2}$	$9\frac{2}{60}$	$\frac{29}{60}$	3.85	$36\frac{1}{2}$′	" " " "
17	" "	21 mg	2 – 25	2′	3 – 08	$20\frac{35}{60}$	$\frac{25}{60}$	1.98	43′	" " 30 gms. "
18	Bone Ash	$20\frac{51}{60}$ mg	2 – 25	2′	3 – 07	$20\frac{24}{60}$	$\frac{27}{60}$	2.05	42′	" " " "
		Wt. Cupel.	Wt. Lead	Wt. after Cupellat'n	Test for Gain	Absorption				
19	Portland Cem.	14.6 gms	25 g	38.220 gms	23.620 gms	being	1.59 times	its	own	weight " Both cupels are same size.
20	Bone Ash	13.079 gms	"	31.935 gms	18.856	"	1.44 "	"	"	"

Summing up and using the results of the few experiments I have made, which, having had to be done in spare moments, are not as many as I would have liked to have done before laying this paper before you, I find results to be as follows:

Time of cupellation about the same.

Loss in cupellation slightly in favour of the cement.

Cement cupels less liable to breakage and fracture in the furnace.

Absorbing power of cement, size for size, greater than that of bone ash.

Cost of cement being only a fraction of that of bone ash.

In sending this paper to be read before you it is in hope that some members of the Society who are interested in assaying may become sufficiently interested in this subject to carry on some more experiments in the laboratory of the school, the results of which I would very much like to know.

N.B.—I neglected to state that the cement cupels are made in identically the same way as the bone-ash ones.

Note.—Portland cement cupels have been in use in the assay laboratory of the School for the past three years. In the Spring of 1899, Mr. Mickle, being unable to get a good quality of bone-ash, commenced some experiments with cement, the result of which led to their almost exclusive use in our laboratory. The only drawback to cement cupels is the fact that after they have been brought to the proper temperature they have to be kept thus for from 10 to 15 minutes before putting in the lead, otherwise "spitting" will ensue.—*Editor.*

PEAT.

ARTHUR G. ARDAGH.

Peat or turf, by which latter name it is generally known by those acquainted with it in the old lands, commands an interest to-day from more than one point of view. While you may be interested in it from a scientific point of view purely—a matter for research, if no further, there are those who have been giving many years and much money in endeavouring to devise suitable machinery for compressing it, and thus to place it on the list of successful commercial industries. Expired patents are legion, and for 30 or 40 years we have records of experiments. I can also assure you that there are also many who, with no interest in its manufacture, are waiting to use it in their homes just as soon as it can be procured.

I would not touch upon the commercial side of the question if we were not as engineers specially interested with that aspect, and in fact a constant question is "Can it be made in paying quantities?"

The fascination of the subject and golden hopes of success have ever brought forward fresh brains and resources to fill the breach. Up to this time commercial success has not been attained, but we have good grounds to hope that we are on the eve of it. Although the public hear less of the subject than formerly, there are many earnest workers employed in solving (and I believe they will be successful, if indeed they are not so already) the difficulties of the situation. I think we have crossed the mountains and are descending the foot hills.

Most of us have gathered our hearsay information in regard to peat from old country people. There are deposits throughout Northern Europe in those countries which have sent our fathers and forefathers here. Ever since Caesar's time, at least, the peat fire has been burning.

Here also in Canada there are deposits of a similar nature, for all peats are not alike. If we class decomposed vegetable matters under the general name of peat, we have deposits formed of decayed grasses, sedges, aquatic plants, etc., we have cranberry marshes and pockets of "swamp muck," as it is called, scattered over the country. The farmer is well acquainted with its qualities who has to fight the swamp fire till the snow comes. Speaking of peat, Dana says:

"In temperate climates it is due mainly to the growth of mosses of the *genus sphagnum*. This plant forms a loose turf, and has the peculiar property of dying at the extremity of the roots below, while it continuously grows and increases above the surface, and by this process a bed of great thickness is formed."

It is specially of this kind of peat that I speak. There are two deposits I know well, that of 4,000 acres in Welland County, and a somewhat smaller deposit in Perth County, north of Stratford.

I believe there are a large number of deposits of this sphagnum peat in Canada. There are, I am told, bogs of excellent quality and extensive area in Newfoundland, Quebec and Ontario. There are huge muskegs in the northern part of Ontario, Manitoba and elsewhere, we know, but they are yet to be proved workable deposits. In Ireland beds of great thickness are found in which are embedded and preserved great oaks of a time long since. The peat is cut year by year off the face of the bank left the previous season. The upper stratum of "recent peat" is more fibrous and the colour brown when dry. In "older peat" there are few traces of fibrous matters, and it presents a pitchy hue when cut. It will dry out more or less brown unless it is puddled, when the density increases the dark colour. The upper stratum is called slave turf, because it can be dug with a slave, an instrument like a spade with a wing to enable the bricks of peat to be cut on two sides with one action. The lower stratum is often not cohesive enough to be handled in bricks as it comes from the bog, and this is tramped on the bank and then moulded by hand. It is called mud turf, hand turf, stone turf, or puddled peat.

The output of these operations is, in general, used locally. Most landlords in Ireland have bogs from which they get their

own supply, and the right to cut peat generally goes with a tenant's lease also.

But as to shipping it to a distance, the bulky nature and the dust prevent this being done to any extent. Hence the great efforts made in every country where peat is found to compress it into a more portable and marketable shape.

The process of excavating and drying the peat as performed on the Ellice marsh, north of Stratford, in 1899 and 1900, was as follows: Trenches were staked out 3′ 8″ wide, and at intervals two men, side by side, were set digging with the ordinary steel spades with lifting handles. The peat was dug out one spading deep at a time and spread along the bank, when this was dry on one side it was stacked in small stooks of four or five with the wet sides out, three or four pieces on end and one on top. Subsequently these stooks were gathered into larger piles to make way for the spreading of a second spading and so on. To gather in the dry peat, portable tracks were laid over the ditches and the peat thrown into trams carrying from ¾ of a ton to one ton and conveyed to sheds or huge stacks to be thatched with lumber or moss.

A factory was erected to press the peat, which at present is shut down awaiting the perfecting and trial of mechanical drying, which is occupying the attention of those interested in the enterprise at present.

There are various dryers about to be tested more fully this summer, enough has been done to warrant our hoping we have overcome this crux.

Peat reabsorbs moisture easily, and if spread in a finely disintegrated state on the surface of the bog it will never dry enough to render artificial drying unnecessary

As to its burning qualities, peat ignites easily, requires practically no draught when once the fire has taken hold, gives intense heat, and a banked fire will not burn out nor will it go out until the fuel is consumed. It burns with a flame for some time, and then for a longer period in red hot coals. The gases emitted in the initial stages of burning are not only innocuous but considered by some medicinal, especially against lung troubles. The percentage of ash will vary with the deposit from which the peat

is taken. The following analysis was made of samples of compressed fuel made from the product of the Welland bog with the moisture reduced to a suitable amount:

Moisture	12
Volatile matter	58.20
Fixed carbon	26.
Ash	3.80

The absence of soot, clinkers and practically of smoke (when burned under proper conditions) are qualities which will appeal to all classes of consumers. Peat in its crude state varies very much in weight—about 600 lbs. to the cubic yard may be taken as a fair density. The fuel as consolidated by the Dickson press will weigh from slightly under soft coal to slightly over hard coal, neither frost nor a damp atmosphere will affect it, but it should be protected from rain.

In the Dickson press the peat, after being broken to a powder in a breaker, is disposed automatically by gravitation towards the lower and stationary dies or moulds, which consist of two steel tubes about twelve inches long, of uniform bore and open at both ends, into which work two punches. Each charge of peat which flows in when the punch rises is compacted into a solid block on the top of the previously made blocks which occupy the lower two-thirds of the tube, and this column of blocks is forced down a distance equal to the depth of the block made, and thus each time one drops out at the bottom. The resistance thus obtained is yielding. Processes which involve the consolidation of the crude peat in a wet or hot state leave it subject to disintegration upon drying or cooling.

To dry peat in the air it must be exposed to the wind in brick form, and never more than 4 or 5 inches thick whatever length and breadth it may have. It will never dry in heaps or in powdered form either, unless it were spread an inch deep on boards, which is practically out of the question. Air drying may be done on racks, but the initial cost of the racks will be large.

I believe that in such a situation as the Ellice bog, where my own plant is situated, that the peat can be easily harvested after air drying with only 25% of moisture. This would make the

task of reducing the moisture another 10 or 15 per cent. by artificial means an easy one.

It is proposed by some to squeeze the first 30 or 40 per cent. of moisture out of it, and for this purpose an hydraulic press has been set up at the Trent Valley Peat Fuel Works. Fresh peat contains from 75 to 90 per cent. of water, which shows what an amount has to be handled to secure one ton dry weight. The time of drying varies with the weather, the handling it gets, and the artificial shelter, if any.

It might dry in a month easily, but count on six weeks on the average.

In well designed plants an endeavour will be made to eliminate hand-labour as much as possible. The plant will cover quite an area of ground, but the storage building will be inexpensive. They will be all connected with conveyors.

Dredging machinery will be used in some bogs, in which case the peat will be squeeed and artificially dried, and what takes now six weeks will occupy less than an hour.

THE CONSERVATION OF WATER FOR POWER PURPOSES.

C. H. Mitchell, B.A. Sc., C. E., A. M. Can. Soc. C. E.

In Canada and particularly in the Province of Ontario where the wealth of water powers is known to be almost inexhaustible, the study of conservation of water for power purposes seems almost superfluous. Conditions, however, frequently arise where the concentration of water at one point from a limited area becomes highly necessary for commercial purposes.

The following paper was prepared in the form of a report, made in October, 1900, for a well known mining company in Ontario, and with their consent the writer has arranged it for the Engineering Society in the hope that it may provide information on a subject upon which but little has appeared in the Society's publications.

The circumstances leading to the examination of this hydraulic proposition required that sufficient water be provided from a very limited area, for the present small experimental plant, and ultimately for a proposed plant of large capacity. The grade of the ore in this locality was such as to render it preferable to develop direct power at this point even at considerable expense for the collection and storage of water. The power is required for running a crushing and washing plant in the process.

General.

1. The mine now worked by your company is situated on Lot 3, Con. xviii., Township of Raglan, with the present mill situate on Lot 2, about a mile distant by road. These works are about 6 miles south of the Village of Combermere, and 20 miles south from Barry's Station on the Canada Atlantic Railway. They are at an elevation of about 200 feet above, and a mile west from the York River, which is a considerable stream tributary to the Madawaska River, the junction of which is about 4 miles north from the mill. This will be seen by reference to the "General Map" accompanying this report.

2. Access is had to the works from Combermere at present by road only, the country being very hilly, and the roads for the

most part rough, though improvements have been lately put on them. Transport can be effected by water via the Madawaska and York Rivers to a point within about 1.5 miles of the works, from which a road is now being constructed. This water is available for 8 months of the year through to Barry's Bay, where a spur track is in contemplation to the wharf.

3. The mill is situated upon a small creek known as Long Lake Creek, and was formerly a small saw-mill, and is supplied with water for power from the creek by means of a small dam. This creek has its sources to the west, and above the junction in the "Menzie Meadow," about 2 miles distant, trends from the north on the one hand from Long Lake (about 200 feet above the mill), and from the west, from a series of small lakes and meadows fed by a considerable area of hilly district. The latter branch is known as Lennon's Brook. At the extreme end of this is a small lake or pond which is called Summit Lake, about 150 feet above the present mill, the waters of which flow westward, though in wet season much of it would come east. This appears to be fed to a large extent by the country to the north.

At a point about 0.75 miles west of the mill, Robilliard's Brook enters the Long Lake Creek. This drains an area in a pocket among the hills in which is a small pond called, by settlers, the Beaver Meadow, some 200 feet above the mill.

To the north-west of Long Lake lies Echo Lake, at an elevation of nearly 400 feet above the mill, which, though of larger area than any lake in the vicinity has a comparatively small drainage area, the water from which flows by Round Lake and outlet to the Madawaska to the north and away from Long Lake.

The greater part of the drainage area outlined above lies in the Townships of Carlow and Bangor, smaller portions being in Raglan and Radcliffe.

4. The general nature of the country is very hilly, with areas of lake marshes and low ground lying between. The hills rise to a general height of about 500 feet above the valley of the Long Lake, and Lennon Brooks, and lie in an irregular position rather than in any particular direction of ridges, a fact which is

favorable for water supply, and storage. The slopes and crests of the hills are covered to a considerable extent with hard wood and second growth brush. The valleys are more or less open, with patches of second growth.

5. The prevailing temperatures in this locality are extreme, the summer average being at times as high as 90 degrees F., and the winter as low as — 30 degrees F., frequently much lower. This is a considerable factor in water supply owing to the evaporation in summer, and the freezing of springs, watercourses, and rainfall in winter.

Rainfall, Sources and Storage.

6. The most essential feature in the supply of water from this locality for power is the available rainfall. Having examined the streams during the first week in October of this year, the writer was able to determine the average fall flow of water available, a part of which, though small in quantity, may be termed "ground water" rising from springs, and quite independent of the rainfall. The rainfall source of supply appears to be variable from year to year, and even by monthly comparison.

The nearest meteorological observing station to this locality is situated at Renfrew, about 45 miles to the east as the crow flies. Observations on rainfall have been carried on at this point since 1884, though at times they have been omitted. and there are some readings which there is reason to doubt. Below is a table showing the totals of annual rain and snow fall equivalents in inches. Observations in the years not shown are incomplete:

	Rain.	Snow.	Total.
1884	13.54	8.60	22.14
1885	16.56	11.48	28.04
1886	19.00	7.35	26.35
1888	13.19	4.35	17.54
1889	23.26	7.87	31.13
1890	17.15	6.70	23.85
1891	21.14	4.71	25.85
1893	22.71	2.76	25.47
1894	13.20	1.75	14.95
1895	9.13	4.47	13.60
1897	13.50	5.20	18.70
1898	19.67	6.45	26.12

The abnormally low rainfall in the years 1894 and 1895 is evidently due to incorrect readings, as an examination of the records would lead one to suspect. Omitting the observations of these two years, the average of 10 years, as above since 1884, is a total fall of rain and snow combined of 24.52 inches, while, including the two years mentioned, it becomes 22.81 inches. The year 1898, being the nearest to the average in recent years, is given below so as to illustrate the monthly variation, although the months September and October are abnormally high:—

Year 1898.

	Rain.	Snow.	Total.
January	0.00	2.00	2.00
February	0.00	1.80	1.80
March	0.62	0.00	0.62
April	0.47	0.10	0.57
May	2.51	0.00	2.51
June	2.87	0.00	2.87
July	2.15	0.00	2.15
August	2.05	0.00	2.05
September	4.09	0.00	4.09
October	4.91	0.00	4.91
November	0.00	0.80	0.80
December	0.00	1.75	1.75
Totals	19.67	6.45	26.12

The average month by month covering the typical years 1885, 1886, 1888, 1890, 1897 and 1898, is given in the following table, which shows the rain, snow and total for each month.

	Rain.	Snow.	Total.
January	0.44	1.25	1.69
February	0.16	1.38	1.54
March	0.32	0.91	1.23
April	0.95	0.95	1.90
May	1.61	0.02	1.63
June	2.70	0.00	2.70
July	2.40	0.00	2.40
August	2.65	0.00	2.65
September	1.85	0.00	1.85
October	2.13	0.04	2.17
November	1.01	0.68	1.69
December	0.13	1.64	1.77

This by inspection would lead to the assumption that while the "dry weather" season occurs in the winter months the precipitation is fairly constant throughout the year, that is to say that the July, August, September and October weather so frequently known as "dry" produces quite as much rainfall as other seasons, and that if there is any shortage of water it is caused solely by evaporation and absorption. The northern country is well known to give a "dry weather" season in March, a fact which is borne out in this locality by the last table, the precipitation being nearly all snow water.

The inference from these tables is that generally speaking the "dry weather" occurs not in the summer or fall, but in February and March, during the extreme cold weather, and that conservation of water must look toward that season and not so much toward the warm summer season.

7. The character of the country has much to do with the securing of rainfall water as under any circumstances a certain portion of the water is lost, the amount depending upon the general inclination of the slopes, and the character of the soil, etc. Flat country and very gentle slopes give a less percentage of the total rainfall capable of being collected and stored, than does steep, hilly and rocky country. This amount of water reaching the basins or streams is termed "run-off." By an examination of all the conditions in the areas for supply for your purposes the writer does not think it wise to assume the run-off in excess of 50%, which is a moderate and conservative figure for such country. The remainder of the precipitation would be lost through evaporation, absorption and seepage into underground channels.

Assuming as an average annual precipitation for calculating purposes the amount of 24 inches, the run-off can be safely assumed as 12 inches of rainfall per annum. Twelve inches of water over one square mile of area would produce about 27,880,000 cubic feet of water.

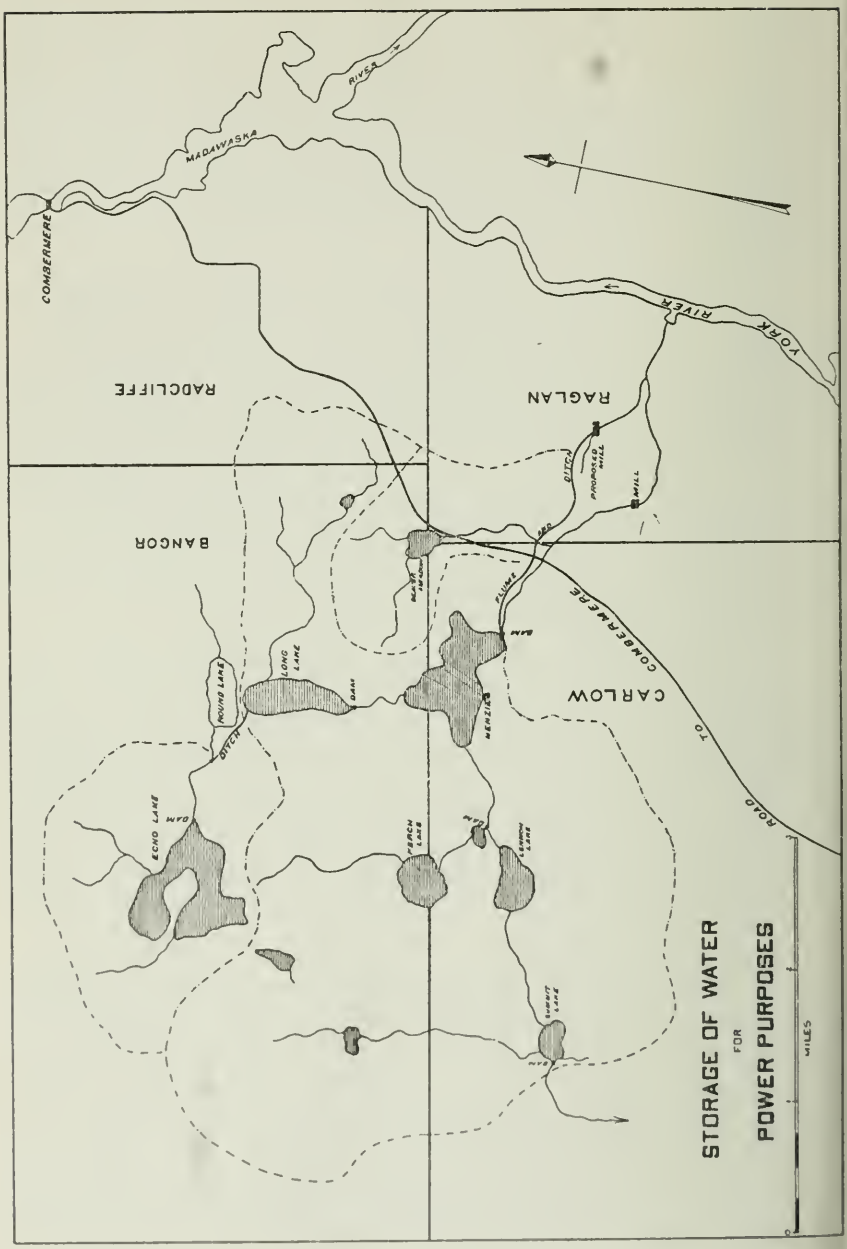
8. The main area as shown on the general map of the supply, comprising Long Lake with its tributaries, and the Lennon Brook, etc., comprises about 13.0 square miles. Within this area there is about 0.65 square miles (5%) or 435 acres of water surface

at ordinary times, *i.e.*, including lakes, streams and marshes. Long Lake has an area of about 90 acres, at its present level. The area of thirteen square miles should produce about 362,000,000 cubic feet of run-off water per annum. The writer estimates the ground water as indicated by the October flow at about 48,000,000 cubic feet per annum, thus bringing the total water available in the main water shed area to a flow of 410,000,000 cubic feet per annum.

By an examination of the average monthly rainfall for many years back, and having regard for the snow, ice and spring freshets, together with an assumed constant ground water flow, estimated approximations for the total monthly flow from this area have been made. These lead one to believe that the average flow during the months of December, January, February and March, will not exceed say 11 million cubic feet per month, and might at extremely cold and dry seasons run as low as 8 million cubic feet. April, May and June might be assumed at an average of from 50 to 70 million cubic feet per month, the other months of the year being from 20 to 40 million cubic feet.

9. The area shown by the general map comprising the "Beaver Meadow" and Robilliard's Brook drainage, gives about 1.5 square miles, of which about 25 acres (2½%) is water surface. Springs in this locality are numerous, and these, together with the rainfall, it might be estimated would give about 46 million cubic feet per annum. This would produce monthly about one-tenth the amounts shown for the general area. The greatest part of the water from this area reaches the Long Lake Creek at a point about ¾ miles above the mill.

10. The Echo Lake area lies high above the previous water sheds, and consists of a drainage of about 3 square miles, of which 250 acres or 10% is water surface. This lake is fed largely by springs, and the slopes are comparatively short and steep. This area should produce with the ground water a total flow of about 100 million cubic feet per annum. The cold weather winter flow should not be less than about 2 million cubic feet per month, the maximum spring flow for three months about 15 to 20 million cubic feet per month, and remaining average about 7 to 10 million cubic feet.


COMBERMERE
MADAWASKA
RADCLIFFE
BANGOR
RAGLAN
CARLOW
YORK RIVER
ROUND LAKE
LONG LAKE
ECHO LAKE
PERCH LAKE
STORAGE OF WATER
FOR
POWER PURPOSES
MILES

Present Mill and Plant.

11. The present mill is situated in the gorge of the Long Lake Creek, immediately below a log and earth dam, about 15 feet in height. The dam was originally built for a saw-mill and was increased in height and strength for the present mill. This impounds water to only a small extent of surface as the creek inclination is somewhat steep. Water for driving the mill is drawn from the dam by means of a 15 inch spirally rivetted pipe to a point about 300 feet below the dam, where power is generated by a 37 inch "Cascade" impulse wheel, with five nozzles, under a normal head of about 44 feet, variable on account of head water; at this head the wheel gives about 39 horsepower. This plant has been in operation only since July, for experimental purposes.

At the time of the writer's visit (October) this wheel was developing about 30 horsepower, and was using about 7 cubic feet of water per second when all machinery was on. The heavy crusher machinery was running at that time only about 4 hours per day out of the 20 hours run, using about 15 horsepower, and the remainder of the time the lighter machinery used only about 15 horsepower, with 3.6 cubic feet of water. The ore treated in the mill was about 20 tons per day of 20 hours, and observations made on the performance of this experimental mill show that it requires about 1 horsepower per ton of ore treated for all purposes, although this should be considerably decreased by improvements which can be made.

12. Measurements of water coming down to the mill show that under normal conditions in October as indicated above, about 5 cubic feet per second of water was being used for all purposes, washing, leakage, and other loss. The latter can be saved by careful attention to the dam, which is now being done.

A series of measurements extending from May 17th to July 12th, 1900, on the water flowing over a 70 inch weir at the mill gives an average discharge of about 60 million cubic feet per month. During this interval, however, a dam was placed in the outlet to Long Lake on June 4th, thereby cutting off supply from that district. Previous to this date the average for the 18

days in May was at 26 cubic feet per second, or at the rate of about 70 million cubic feet per month. This figure includes the Robilliard area, but does not include the water from the west end of the main area, which it is contemplated to bring to the mill. Though the rainfall at Renfrew for the first five months of 1900, and for the month of May, shows about 25% greater than the average for the periods, as indicated in paragraph 6 above, nevertheless the above discharge as measured appears to agree with the run-off production indicated in paragraph 8. After the dam was placed in Long Lake the rate of flow for 38 days in June and July was 20 cubic feet per second, or about 53 million cubic feet per month, during which time Long Lake was filling according to subsequent measurements at the rate of about 5 million cubic feet per month. These figures also appear to agree fairly well with the previous deduction from the rainfall and run-off.

13. There is no doubt whatever that this flow of 5 cubic feet per second as measured cannot be maintained throughout the winter months or during a particularly dry season in the fall. This is shown by the fact that the present plant has been drawing to a small extent this year upon the Long Lake reservoir since August 24th. This lake was dammed on June 4th by a small dam and allowed to fill until the former date to a height of about 30 inches. Since that time water has been drawn from it at the rate of about 0.7 to 1.0 cubic feet per second, of which from 0.4 to 0.5 cubic feet is storage water.

While a minimum of water of about 5 cubic feet per second will be required to be maintained during the present winter, a greater amount, about 8.0 cubic feet per second will be required next year in view of the contemplated enlargement of the present experimental mill, when a wheel of greater power may be installed. A 50 horsepower wheel could be run with this water on the same principle as at present, running all the machinery at full power about one quarter of the time, and the lighter machinery at about 20 horsepower during the remainder.

Proposed for Present Plant.

14. The present dam will require to be carefully overhauled and strengthened so as to ensure its security and close the leaks.

The stability of this dam is most essential, as the mill is situated immediately below it. The immediate construction of a sufficient spillway through the dam to provide for the spring freshets, is advisable, the former wasteway having been closed, and it would be well also to clear the mill pond of brush and logs, etc.

15. The chief problem for the present plant is to provide the supply of 8 cubic feet of water at the mill the year round. To do this requires the utilization of storage areas sufficient to store water to supply the deficiency in the dry and cold weather months, viz., December to March, inclusive, and possibly October and November at times.

The writer is of the opinion that the main area, together with the Robilliard area, as before indicated, will provide sufficient run-off water to do this, and that storage reservoirs in the Menzie Meadow and on Long Lake can be suitably arranged to store water for the dry seasons.

Assuming that the minimum dry season produces by the run-off from these two areas 8 million cubic feet per month for the four winter months, December, January, February and March, and 18 million cubic feet per month for October and November, which is a conservative figure, the storage areas must supply the deficiency up to the 8 cubic feet per second limit. The amount of water required by the mill at this figure running 24 hours per day, 31 days in the month, will be approximately, 22 million cubic feet per month. Consequently the draft on the storage areas would be 14 million cubic feet per month for the winter months and 4 million cubic feet for October and November. That is to say a total of 64 million cubic feet would be required, without considering losses by evaporation, freezing, absorption, etc.

16. To provide for this, dams for storage will be required at the outlets of the Menzie Meadow, and Long Lake.

The Menzie Meadow dam is proposed at the point shown in the plans, and should be built so as to impound water to an elevation of 185.0 feet above the datum of levels as per the contour plan, or about 14 feet above the level of the creek immediately above the outlet. This dam can be built of logs, earth and stone, which can be easily found in the locality. Its extreme height

would be about 17 feet and its length about 200 feet, at the located site, assuming the water to be within a foot of the top at high water, the crest of the dam being at elevation 186.0. This dam should be made perfectly tight and with a spillway to provide the passage of high water in the spring. It should have stop logs or a gate so arranged as to deliver the required amount of water over and into the creek bed. The amount of water delivered will not need to be as much as 8 cubic feet per second as the Robilliard stream and springs in the valley will provide a portion of the water required for the mill.

The Menzie Meadow thus dammed so as to raise the water to an elevation of 185.0 would provide for a storage of about 83 acres, which, with the dam arranged so as to draw off the upper 13 feet of the pond, would store about 46 million cubic feet. The evaporation and absorption during the summer months, together with temporary loss in the winter by frost, should not exceed about 20% of the amount if the brush and trees, particularly within the upper pond area, are cleared so as to reduce the evaporation to a minimum. The writer is of the opinion that a storage of 37 million cubic feet can be considered as reliable for this reservoir, at the height of dam indicated. Should more water be required at any time in the future, it can be impounded by raising this dam a few feet; the dam might be built with this in view.

It appears from the precipitation that there will not be sufficient rainfall this fall and winter season (1900-1901) to provide any water for storage above that now being used, but the immediate construction of this Menzie dam is advisable, so that when the spring thaw and rains set in the reservoir may be filled by the flood water. This water will then become available in the fall and winter of 1901.

The dam placed at the outlet of Long Lake in June, 1900, serves to raise the water about 2.5 feet. If this were raised so as to impound water to a depth of 10 feet above the old lake level, a storage of about 42 million cubic feet would be secured. Deducting about 20% as before, for evaporation, etc., about 34 million cubic feet would be available. This is quite feasible and its construction during the coming winter is also advisable to

secure the flood water in the spring. The area draining into Long Lake is not large, and would not be sufficient to fill the pond as proposed unless the outflow were shut off entirely. This, however, can easily be done, as the surplus water from the western portion of the main area, coming to and over the Menzie dam would be sufficient to run the mill. With a properly constructed dam and excavation the water of Long Lake could be drawn down even lower than originally.

17. For the demands of the coming dry winter season, before these dams fill, steam power will be required if the mill is to be kept running. Under the present circumstances a 15 horsepower steam plant ought to be quite sufficient as an auxiliary to the water plant with what water comes down. This can subsequently be used for heating and other purposes.

The following is a recapitulation of the works proposed for improving the present plant:—

1. Strengthening present mill dam, stopping leaks, constructing spillway, and possibly ultimately raising crest.

2. Possible ultimate installation of larger wheel and feed pipe, for say 50 horsepower.

3. Building Menzie dam, and clearing area.

4. Building Long Lake dam.

Water provided—8 cubic feet per second.

Available water stored—71,000,000 cubic feet.

Proposed New Mill.

18. There is in contemplation, the construction of a new mill at the location shown on the plans, of much greater capacity than the present experimental mill, if the construction is justifiable by circumstances. Such a course would entail the abandonment of the present mill, and the use of the machinery and the water for the new plant. The following hydraulic considerations are upon this basis.

19. As has been previously shown the total water available from the three drainage areas is constituted of: main area, 410 million cubic feet per annum, Echo Lake area 100 million, and Robilliard area, 46 million, a total of 556 million cubic feet. Of

this, by a conservative estimate, more than 80% could be utilized for the mill, or say a maximum of 444 million cubic feet, a monthly average of 37 million cubic feet. This is at the rate of 14 cubic feet per second used constantly.

It appears from previous figures that the dry weather flow for the four winter months will not exceed 11 million cubic feet per month from all sources; and that the months of October and November cannot be depended upon beyond 25 million cubic feet per month. Hence a deficiency of water under the requirement of 37 million cubic feet per month, occurs in six months of the year, the draft for the four winter months being at the rate of 26 million, and for October and November 10 million, a total deficiency for the year of 124 million cubic feet, without considering evaporation, etc.

20. The proposed location of a new mill of large capacity, as shown on the plans, is in a ravine immediately below the mine. The advantages of this location are evident. Ore can be sent direct to the mill by gravity, with a short haul. A very high head of water can be secured, and transport for produce easier. A possible advantage is its location out of the line of discharge from the country above, should any of the storage dams go out.

As shown by the map, a mill could be constructed with a water wheel at elevation about 20.0 feet above datum. As previously shown, the elevation of the surface of the storage reservoir at Menzie's already proposed, about 2 miles distant, is 185.0, a difference of 165 feet. This head of course could not all be utilized, as it is proposed to draw the storage of the Menzie reservoir down to elevation 172.0, and as about 18 feet head will be lost in bringing water down the valley, thus leaving an available head on the wheel of 134 feet. Fourteen cubic feet of water per second as is shown above appears to be the maximum which with close regulation can be depended upon as a supply from the areas. This amount of water with 134 feet head would provide 180 horsepower on the shaft for the new mill, running constantly.

Proposed Works for New Mill.

21. The proposition of securing such a large percentage of the total available supply from the areas and storing say 150

million cubic feet (124 million to be available), though quite feasible, will require the utmost attention to construction and regulation to ensure success. The sites for storage are four in number, as follows:

(1) Menzie Meadow. As before proposed, with a dam, however, 5 feet higher, at which level it is estimated 66 million cubic feet can be stored above elevation 172.0, of which, after deducting 20% for evaporation, etc., 53 million cubic feet should be available.

(2) Long Lake. As before proposed, at same elevation, and capacity, viz., 34 million cubic feet.

(3) Echo Lake. By means of a dam at the outlet of Echo Lake, 6 feet in height, 66 million cubic feet could be impounded in the 250 acres extent above the present level. Deducting from this the 20% for evaporation, etc., as before, there would be 53 million cubic feet available water.

(4) Perch Lake. A small storage reservoir can be made in this locality by the construction of a dam at the outlet to its waters. This dam at a height of not more than 10 feet will impound at least 24 million cubic feet, or say 20 million available, though it would not be necessary unless difficulty were found in filling the other reservoirs, or it might be built instead of raising the Menzie dam. It would also be found difficult to fill a dam at this point if water was also being impounded at Menzie's, as the 14 cubic feet flow to the mill must be maintained.

A small storage reservoir could also be made available at the Beaver Meadow, though it is a question if it would be wise or would pay, as the road would require to be moved east up the hill, at considerable expense.

No doubt difficulty will be found in securing the storage of these waters simultaneously, while at the same time maintaining the adequate supply to the mill. This can be arranged only by close regulation of the discharge through the different dams in the spring.

22. A small dam will be required at the western outlet of Summit Lake, so as to turn its waters eastward, also the eastern high water outlet improved and deepened through the marsh.

23. The means of getting the available water to the mill will require considerable work, and comprises the main part of the expense of the project.

Echo Lake lies nearly 200 feet above Long Lake, the brook outlet being very rapid, and falling into Round Lake some 23 feet below the level of Long Lake. Consequently to secure the waters of Echo Lake for power purposes, a conduit will be required from some point on this brook such that the water may be carried over to Long Lake. The proposed location of this is shown in the general plan, and is about 2,400 feet in length, following around the base of the hill which is more or less rocky. This will necessitate the construction of a small flume rather than of a ditch, although part of it might be ditched. A ditch or flume of about 2.5 square feet wet cross section should be sufficient with the grades. The water may be caught at the Echo Lake Brook by a small log dam at the outlet of the lake above. The construction of the latter dam is recommended at least a year before its water will be required.

The Menzie dam being the lowest point on the storage areas, should be specially arranged with regulating gates, easily operated. Irrespective of the level of the water in this reservoir its discharge should at all times be delivered to the head bay immediately below the dam at an elevation of 172.0 so as to provide the drawing out of all the water above the dam. From this point to the proposed forebay above the mill is about 9,400 feet, following the course of the proposed flume and ditch line as shown on the contour plan. This conduit is proposed at a grade throughout of about 0.20% or 1 foot in 500, with a wet cross section of about 6 square feet; in ditch, in earth and gravel the water would be about 18 inches deep, the bottom width 2 feet and slopes 1 to 1½, while in flume the width could be 3 feet and depth of water 18 inches. These dimensions would discharge 14 cubic feet per second at the mill.

There are at least two points where the water will require to be carried by flume, viz., at Robilliard Creek, and at the ravine to the east. There will be other points also where it may be cheaper to flume than blast rock. It may be assumed that of the 9,400 feet total length, 1,200 feet would be flume.

Under this plan the waters of the Robilliard area will require collecting at a point above the flume line, and to be led by a small ditch or flume to the main line. This could discharge constantly.

The proposed ditch line will intercept all water coming to it from the hills to the north, but cannot secure water coming to the present creek bed from the south. This water would be but little, but could be caught at the present mill dam and might be utilized in some manner.

When this ditch is cut through sandy or loose soil, or in loose rock, it should be lined with clay or clayey gravel to make it tight. Difficulty will no doubt arise in any case for the first year or so by this absorption and loss by leakage, but as the ditch gets silted up this will disappear.

24. The works at the forebay on the side hill above the mill should be of sufficient size and capacity to regulate the flow of water through the penstock, deliver the surplus over a spillway, take care of ice, brush, leaves, etc. The penstock to the mill should be 24 inches diameter steel pipe riveted, and should be anchored down the slope to the mill.

A difficulty arises in regulation of the water supply to the penstock at the forebay. The supply coming down the ditch must necessarily be constant unless partially shut down for more than a few hours, consequently provision must be made for the spillway of surplus water. This can be done either at the forebay or at the mill. If at the mill its value is lost unless it can be utilized at periods when it is discharged as surplus. It is recommended then to provide a small reservoir in the ravine above the mill, providing a head of say 60 to 80 feet, into which surplus water of a few hours shut down or slack discharge can be spilled. This can be done by a small dam at slight cost. The water from this can be carried down to the mill and utilized for the washing processes and other work, perhaps to run the lighting.

The power at the mill can be developed by an impulse wheel, such as either the Cascade, Pelton or American Impulse, with two or more nozzles, upon the number of which the size will depend.

The tail water can be disposed of without difficulty as there is a good fall to the York River.

25. The following is a recapitulation of the proposition for the new mill:

Water provided—14 cubic feet per second.
Available water stored—140 million cubic feet.
Working head—134 feet.
Available on shaft—180 horsepower.

FINAL.

26. It has been found that as the timber is cut off and the country cleared near the sources of streams, the yield of water decreases. This affects the run-off as the evaporation is more likely to increase. In the present instance, however, it is not expected that the general conclusions would be affected, as the district can not be said to be heavily wooded, and the water coming down more readily in the spring would be caught by the dams.

27. The advantage of having the mill near the present deposit of ore, which is the best of those owned by the company, is considerable, and if a new mill of large capacity were built in the proposed location, no risk will be run with regard to the power. If some years hence it were found that the available water collected from all sources failed to a serious degree by climate changes in rainfall, or by the clearing of land, power can be obtained by electric transmission from sources elsewhere.

The writer understands that a considerable power is available at Palmer's Rapids, on the Madawaska, 6 miles below the mill, and that other powers now owned by the company exist 20 miles up the York River, distances which are quite feasible for electric transmission. These powers will no doubt be developed in the near future in any case, for other purposes, such as for mining and electric railway, which is already talked of in the locality to connect with railroads to the south.

SOME NOTES ON GREATER ONTARIO.

E. V. Neelands, '00.

In attempting a description of the vast country to our north, which has been not inaptly termed "Our Northern Heritage," the writer proposes to confine himself exclusively to the more unknown portion, north of the "Great Divide," between the waters flowing south to the St. Lawrence system, and those draining into Hudson's Bay, whose southern boundary is roughly determined by the Canadian Pacific Railway. The enormous extent of this territory precludes anything in the nature of a thorough investigation in a paper of this character, and necessitates a statement rather than a discussion of the facts. I will, therefore, endeavour to present in as brief and concise a manner as possible, an account of the district, its nature and resources.

Regarding the region from a geographical standpoint it may, like ancient Gaul, be divided into three parts. Roughly parallel to the C. P. R., a rocky belt traverses almost the entire district from the Ottawa river to the Manitoba boundary. To the north of this in the eastern portion, a clay area, in shape, a rough triangle, extends from Temiscamingue and Abitibi to the Missanabie river. Arable land also occurs in the valley of the Kaministiqua river to the west of Thunder Bay, and in several parts of the Rainy River District. From the northern boundary of the clay land, which in the Moose river basin coincides roughly with the northern limit of the Archean rocks, to the bay, lies an enormous swamp area, practically devoid of timber except small scrubby spruce and tamarac, and underlaid by palæozoic rocks of Upper Silurian and Devonian age.

The northern boundary of the rocky belt follows the eastern bank of the Montreal river from Lake Temiscamingue, and crosses the Nipissing-Algoma boundary line at a point about one hundred and twenty-four miles north of the C. P. R. It then is roughly

traced by Niven's Base Line Lat. 48° 27′ 54″ to the Missanabie river. Here it bends to the north and areas of clay occur on the Ka-hina Kagami and Kenogami rivers to the west, whose southern limits probably represent its continuation. Farther to the westward rocky country generally prevails to the Rainy River District. Rocky areas also occur farther north in some parts, the most important being a ridge of considerable elevation forming the Height of Land between the Abitibi and the water flowing south to the Quinze. The principal formations in this district are the Laurentian and Huronian, widely spread throughout the whole region and consisting mainly of gneisses and green schists, and the Animikie or Nipigeon series in the vicinity of Thunder Bay. Cambrian rocks occur to the north-west of Sudbury, and a small area of Niagara Limestones and Dolomites is found to the north of Lake Temiscamingue and on some islands in the same lake.

It is in this region that the economic minerals, and to a large extent the timber of Greater Ontario are to be found. Valuable finds of iron, nickel, copper, zinc, gold and silver, all of which are mined farther south, are reported from the northern portion of the district, but as little or no work has been done up to the present time nothing very definite as to the extent of the deposits can be said except that the most promising surface showings occur in many parts.

The timber of the district is a less doubtful quantity. White and red pine occur up to Lake Abitibi in the east, but nowhere else east of Lake Superior is it found so far north. In the Rainy River District it is abundant in the south, and is found sparingly as far north as Lac Seul. Banksian or jack pine, white and black spruce and tamarac, poplar, balm of gilead, white and red birch and cedar occur everywhere throughout the district, jack pine being usually found on the sandy ground, spruce and tamarac in wetter country, and the others along the banks of rivers. Fire has played great havoc in the timber of this district, especially in those parts adjacent to the railway, and unless the trees are protected by nature in some way they are usually burned before maturity.

The northern limit of the clay belt cannot be well defined, as it is impossible to draw a sharp line of demarcation. Good land is

found generally as far north as Lat. 49° 15′, on the Nipissing-Algoma line, beyond which it gradually merges into muskeg. Farther north small areas of arable land occur, usually in the neighbourhood of rivers, but generally the country is unfit for cultivation.

Everywhere in this district the common garden vegetables, potatoes, cabbages, cauliflowers, etc., mature without difficulty. Every Hudson's Bay Post has its garden, and the officers of the Company raise with little trouble such green stuffs as they require. Except in the Temiscamingue and the Rainy River Districts, cereals have not been seriously attempted, but there is no reason to suppose that in the southern parts of the country they could not be cultivated with as much success as in districts to the west in the same latitude. Barley has been grown at Moose Factory, but its ripening cannot be depended on as severe frosts frequently occur early in the autumn and sometimes even during the summer months. Farther south the crops would be much safer, as low temperatures are the exception rather than the rule. In the past summer the thermometer did not fall below the freezing point from June 1st to Sept. 8th in the region north of Lake Superior, and I was informed by the officer in charge of Long Lake House, which is situated about eighty miles north of Jackfish Bay, that it was a fair average summer as far as the temperature was concerned.

The timber in this region is similar to that further south, being mainly spruce, tamarac, jack pine, poplar, birch, balm of gilead and balsam. The trees sometimes attain a diameter of thirty-six inches but the average of the larger sort is not above fifteen. The country has been burned everywhere except near water and the second growth is very thick, so that the majority of the trees have not an opportunity to mature. Along the rivers and on the lake shores the timber is larger but has a tendency to be very knotty and twisted.

North of the clay region the country becomes more swampy and finally merges into open muskeg, often as bare as the prairies of the west for many miles, the only break in the landscape being a few clumps or ridges of small stunted spruce and tamarac. The surface of the country is covered with moss many feet thick, which

often stretches across large areas of water, lying on its surface like a blanket and quivering under every footstep. Dry land seldom occurs except in the immediate neighborhood of running water, where clay banks rise up like dykes and separate the rivers from the swamp. On these banks the only large timber is found, usually in a belt not over a few chains in width and frequently even less. In many cases, where the river banks are upwards of thirty feet above the water, open muskeg occurs within a hundred yards of the stream.

In the spring the rivers, whose water volumes are subject to enormous variations, often overflow the banks, and during the dry season the extreme flatness of the country prevents an adequate drainage. This, in addition to the water formed by the snow melting over such large areas, largely accounts for the swampy nature of the country.

The character of the rivers alters greatly immediately upon entering this region. In the south they are usually swift flowing streams with abrupt descents over ledges of rocks, but in the great muskeg district they cut wide channels for themselves, since the erosion of the soft banks is much more rapid than that of the bottom—which is usually flat-lying limestone strata. As a result the great rivers entering James' Bay have strong heavy currents and are wide but very shallow. The Moose at the mouth is about two miles in width, but the depth is seldom greater than a few feet; and the Abitibi can be crossed on foot in places where its width exceeds half a mile. No portages occur on the Abitibi for about 50 miles from its junction with the Moose, and the navigation of the Moose is uninterrupted for considerably over a hundred miles, and that of the Albany for over two hundred. Numerous smaller streams show similar characteristics, which demonstrates the flatness of the whole region. These rivers are all very sensitive with regard to water volume. Nominally the streams flow over flat-lying rocks and have sloping banks covered with alders and "blue joint," crowning the banks are fringes of timber, which mark the high water level, usually many feet above the stream in the autumn. At New Port, about one hundred miles up the Abitibi, accurate measurements showed the spring level of the water to be thirty feet above the river in September.

The only minerals of economic importance in the district are gypsum and lignite coal. The former occurs in large quantities on the French river, a tributary of the Moose, and also on the Missanabie, and a bed of the latter crosses the Abitibi at the Blacksmith's Rapids about thirty miles above the Moose. Lignite also exists on Coal river, a tributary of the Missanabie. Though not extensive these deposits are important as proving the existence of lignite in the region, and it is possible that future exploration may reveal large quantities of this mineral. An analysis of the coal from the Abitibi deposit, by W. A. Parks, Ph. D., gave:

Fixed carbon, 50.408 p. c.

Volatile matter, 38.63 p. c.

Moisture, 8.016 p. c.

Ash, 2.945 p. c.

Heating power, 6995 cal.

Perhaps this region is most important as a source of peat. It is claimed that the moss of the muskegs when decomposed forms peat of an excellent quality, and if this is the case the value of our wild, useless swamp lands is inestimable. The muskegs of value from this standpoint are very widely spread throughout the whole of Greater Ontario. Large areas occur in the Rainy River District and eastward to the great muskeg region in the basins of the Lower Moose and Albany rivers.

It seems probable that the water power now being wasted throughout the whole of Greater Ontario will be a very potent factor in commercial industries of all kinds when the country is opened up. Few countries are better supplied with natural power than this district. The number of rivers of large size with practically an unlimited water supply, and having usually very abrupt descents is sufficient in itself to guarantee that abundant power can be developed to supply all the needs of the country.

In conclusion is appended a list of what may be regarded as the more important resources of the country, and also a table showing the mean monthly temperatures at Moose Factory during 1878 and 1879.

Minerals.

Coal.—Deposits of Lignite on Coal and Abitibi rivers.

Gold.—Found on Sturgeon Lake, Lake Seul, Lake Minnetakie and other points in the Rainy River District. Along the north shore of Lake Superior and in parts of southern Algoma and Nipissing.

Silver.—Found at several points along the north shore of Lake Superior.

Iron.—North shore of Lake Superior and in parts of the Rainy River District and in southern Algoma and Nipissing.

Copper.—Same localities as iron.

Graphite.—Found in some districts north of Lake Superior.

Zinc.—North of Lake Superior.

Nickel.—Reported in districts north of Sudbury.

Anthraxolite.—Found in districts north of Sudbury.

Timber.

White Pine.—North of the Temagamingue country, and about the head waters of the Mattagami, also in the Rainy River District.

Red Pine.—Same as white pine.

Black Spruce.—Very common throughout the whole district.

White Spruce.—Found everywhere but less common than black spruce.

Banksian or Jack Pine.—Common everywhere on the more sandy soil.

Tamarac.—Common throughout the whole district especially in swampy parts.

Poplar.—Common on clay land and near water.

Balm of Gilead.—Same as poplar.

Birch.—Common throughout the whole district, found in same localities as poplar.

Balsam.—Common on clay land and near water.

Cedar—Occurs throughout district, generally in swamps or near water.

White Elm.—Found sparingly in Rainy River District and in the more southern parts.

Black Ash.—Occurs occasionally in the south and is of small size.

Fur and Game.

Black Bear.—Common in certain localities.

Polar Bear.—Occasionally seen about Moose Factory.

Moose.—Common in the more southern parts and in the Rainy River District, rare north of Lake Superior.

Woodland Cariboo.—Common in most parts except in the wetter muskegs.

Beaver.—Common in most parts.

Fox.—Common throughout the district.

Otter.—Common in most districts.

Marten.—Common in most districts.

Mink.—Common in most districts.

Fisher.—Common in most districts.

Weasel.—Common in most districts.

Musk-rat.—Common in most districts.

White Whale.—James Bay.

Lake Trout.—Common in larger lakes.

Sturgeon.—Found in some of the larger lakes and rivers.

Brook.—Common in many streams.

Pike.—Very common, found in nearly all lakes and rivers.

Pickerel.—Common.

Sucker.—Common everywhere.

White Fish.—Found in many lakes and streams.

Ducks.—Many varieties found everywhere in the district.

Geese.—Common in the district though only in the spring and fall.

Partridge, Grey and Spruce.—Common everywhere.

Prairie Chicken.—Common in parts of the Rainy River District, and said to be coming east along the burnt land about the C. P. R.

Table showing mean monthly temperatures at Moose Factory.

Months.	Temperatures Fahrenheit 1878, 1879.	
January	— 1.07°	— 3.92
February	13.71°	— 6.72
March	20.39°	12.08
April	35.59°	24.19
May	47.32°	39.95
June	57.04°	50.24
July	66.91°	60.26
August	62.99°	57.78
September	51.66°	48.98
October	40.94°	45.14
November	26.48°	20.80
December	7.57°	— 11.20

THE MADISON DRAW BRIDGE AT PORTLAND, OREGON.

By H. G. Tyrell, C.E., '86,

Designing Engineer for Boston Bridge Works.

The following bridge work is believed to be a typical case of first-class American Draw Bridge practice, and it is offered to the Engineering Society with the hope that it may be useful and interesting.

My calculations and strain sheets are given in full in the order that they were made.

In October, 1899, the City of Portland advertised for designs and bids for a highway and double track street railway bridge to cross the Willawette River at Madison Street, the bridge to replace the wooden one then in place.

The new bridge to consist of one steel swing span 316 feet long, and a width of 25 feet centre to centre of trusses, and a total width out to out of hand rail of 40 feet, and seven Pratt combination fixed spans of 190 feet in length each, and the same width as the swing span. The whole to be designed according to Thatcher's specification of 1894, with the following conditions:

Concentrated Live Load—2 electric cars coupled, on each track, weighing 20 tons each, or 15 ton road roller.

Uniform Live Load—100 pounds per square foot all over.

Roadway Floor—5-in. wood paving block on 3-in. plank, laid with $\frac{1}{2}$-in. open joints, on 6 x 8 joist laid cross-wise of bridge $2\frac{1}{2}$-ft. centres. All the above supported on steel stringers about 5-ft. apart.

Sidewalk Floor—2-in. plank on wood joist.

Roadway will be crowned 3 ins., and have cast scuppers in alternate panels on each side. Wood paving blocks 4 in. x 8 in. x 4 in. boiled in asphalt.

Material—Lateral rods, iron; drum and loading beams, soft steel; balance, medium steel.

Unit Stresses—Tension Only.

Chords, Ties, Counters, and Long Suspenders—

Wrought Iron.	Soft Steel.	Medium Steel.
$9400\left\{1 + \frac{\text{Min.}}{\text{Max.}}\right\}$	$10800\left\{1 + \frac{\text{Min.}}{\text{Max.}}\right\}$	$11700\left\{1 + \frac{\text{Min.}}{\text{Max.}}\right\}$

Plates and Shapes—

$8500\left\{1 + \frac{\text{Min.}}{\text{Max.}}\right\}$	$9700\left\{1 + \frac{\text{Min.}}{\text{Max.}}\right\}$	$10500\left\{1 + \frac{\text{Min.}}{\text{Max.}}\right\}$

Tension Flanges of Built Beams Girders, Same Gross Area as Compression Flanges.

Floor Beam Hangers through pin holes—

	Wrought Iron.	Soft Steel.	Medium Steel.
	6800	7800	8400
Lateral Rods	20000	23000	25000

Compression Only.

Flat Ends	$10750 - 399\frac{l}{r}$	$12500 - 500\frac{l}{r}$	$13750 - 577\frac{l}{r}$
One flat & one pin	$10750 - 444\frac{l}{r}$	$12500 - 556\frac{l}{r}$	$13750 - 642\frac{l}{r}$
Pin Ends	$10750 - 489\frac{l}{r}$	$12500 - 612\frac{l}{r}$	$13750 - 707\frac{l}{r}$

Lateral Struts, add 25% to above units for pin ends.

l=length of member in feet.

r=least radius of gyration in inches.

For top chords the stresses per square inch due to weight of member will be deducted from the above unit stresses.

The reduction for chords flat at one end being one-half, and for chors flat at both ends, one-third of the amount for members with pin ends.

No allowance will be made for wind stress combined with stress from dead and live load, unless the combined stress exceeds by 50 per cent. the stress from dead and live load only, in which case the combined stress will be used with a unit stress 50 per cent. greater than above given.

Girders.

In the compressed flanges of beams and girders, the allowed stress per square inch shall not exceed—

	Wrought Iron.	Soft Steel.	Medium Steel.
For riveted girders,	$\frac{9400}{1+.0288\frac{l^2}{b^2}}$	$\frac{10800}{1+.0288\frac{l^2}{b^2}}$	$\frac{11700}{1+.0288\frac{l^2}{b^2}}$
For rolled beams,	$\frac{10000}{1+.0288\frac{l^2}{b^2}}$	$\frac{11500}{1+.0288\frac{l^2}{b^2}}$	$\frac{12500}{1+.0288\frac{l^2}{b^2}}$

l = unsupported length in feet.

b = width of flange in inches.

Floor beams and stringers will be considered unsupported between end bearing.

Alternate Tension and Compression.

For the greater stress—

$$9400\left\{1-\frac{\text{max. less}}{2\times\text{max. greater}}\right\} \qquad 10800\left\{1-\frac{\text{max. less}}{2\text{ max. greater}}\right\}$$

$$11700\left\{1-\frac{\text{max. less}}{2\text{ max. greater}}\right\}$$

For compression only use compression formula.

Use the one giving the greatest area of section.

Combined Stress.

A member subject to transverse stress in addition to the tension or compression due to its position shall be considered as a beam of one panel length supported at the ends, for section in centre of panel, and fixed at ends, for sections at ends of panel. The member will be proportioned to sustain the algebraic sum of the stresses resulting from direct compression or tension and the transverse loading in which the allowed stress per square inch will not exceed—

	Wro't Iron	Soft Steel	Med. Steel.
At centre of panel	10000	11500	12500
At end of panel	12500	14400	15000
On pins and rivets shearing	9000	10000	11000
On webs of girder	6000	7000	7500
Diam. of pins and rivets bearing.....	15000	17000	19000
Extreme fibre of pins bending	20000	23000	25000

Field rivets will have 25 per cent. excess section over the above requirements.

Timber.

Fibre stress 1200 pounds per square inch.

Flat ends ..... $1075 - 112\frac{l}{d}$

One flat and one pin ..... $1075 - 125\frac{l}{d}$

Pin ends ..... $1075 - 138\frac{l}{d}$

l=length of member in feet.

d=least diameter in inches.

Shearing—Sliding the grain = 130 pounds per square inch.
Direction of " = 1200 " "
Perpendicular " = 300 " "

Wind Bracing—Bottom lateral bracing will be proportioned to resist a uniformly distributed moving force of 300 lbs. per lineal foot.

Top lateral bracing to resist a uniformly distributed moving force of 150 pounds per lineal foot.

Track Stringer.

Steel, 21 feet long, about 5 feet apart.

M uniform live $= \frac{5 \times 21.1^2 \times 100}{8} = 25326$ foot pounds.

M from road roller = 5456 × 8 = 43648 foot pounds.

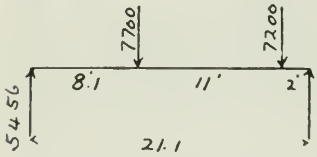


FIG I

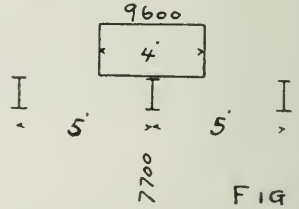


FIG 2

For dead moment, assume weights as follows:

4-in. paving @ 5 lbs.	=	20	lbs.
3-in. plank @ $3\frac{1}{2}$ "	=	10.1	" $\frac{1}{2}$-in. open joints.
Rails		4.	"
Steel		9.	
6 x 8 cross joist $2\frac{1}{2}$ ft. c to c.		5.6	"
		48.7	" per sq. ft.

Then M dead $= \frac{48.7 \times 5 \times 21.1^2}{8} = 13551$ ft. lbs.

M live ..... 43648 "

M total = 57199 "

Try riveted stringer—21 ft. long, unsupported sideways 4 angle's 5 × 3 × $\frac{5}{16}$ 1 Pl.

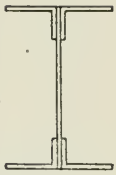


FIG 3.

Allowable stress per square inch =

$$= \frac{11700}{1 + .0288\frac{l^2}{d^2}} = 10430$$

Required depth of web $= \frac{57199 \times 12}{10430 \times 4.8} = 13.71$

Distance back to back = 13.71 + 2 (.68) = 15.07 inch.

Weight per lineal ft. = 45.55 lbs.

Try beam stringer, 21 ft. long, unsupported sideways, floor support not considered.

Allowable stress per sq. in. $= \frac{12500}{1 + .0288\frac{l^2}{d^2}} = 8800$ lbs.

Required S $= \frac{57199 \times 12}{8800} = 78.$ S for 18 in. I @ 55 lbs. = 88.

Try beam stringer braced sideways, 10 ft. between supports. Allowable stress per square inch = 11400 lbs.

Required S $= \frac{57199 \times 12}{11400} = 60.2$ 15 in. I. @ 45 lbs. will do.

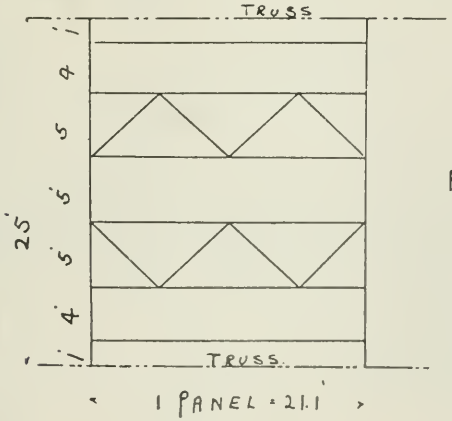


FIG 4.

Weight of stringer bracing for 2 beams:

4 angles $2\frac{1}{2} \times 2\frac{1}{2} \times \frac{1}{4} \times 7$	112 lbs.
5 pls. $8 \times \frac{1}{4} \times 1$ ft. – 3 ins.	40 "
5 angles $2\frac{1}{2} \times 2\frac{1}{2} \times \frac{1}{4} \times 1$ ft. – 3 ins.	25 "
60 rivets	20 "
	197 "

For 1 beam = 98.5 lbs. = 4.7 lbs. per ft.

Beam.....	45.0	"	"
Total.....	49.7	"	"

Comparative economy of 3 stringers:

Built stringer, 45.55 lbs. @ .0267c. per lb.	= 1.2282c.	
18 in. I @ 55 lbs. @ .0247c. per lb.	= 1.3585c.	
15 in. I @ 45 lbs. @ .0237c. "	= 1.0665c.	Use this.
Bracing 4.7 lbs. @ .0275c. "	= .1292c.	Use this.
	1.1957c	

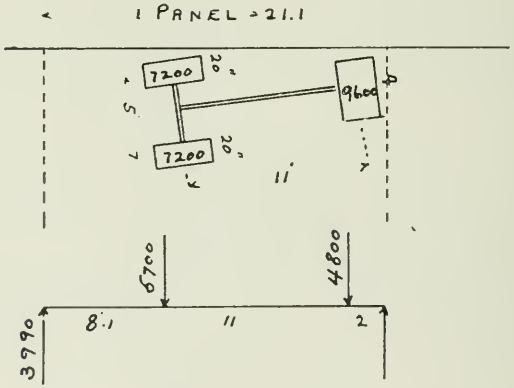


FIG 5.

Side stringer. M uniform live = $\frac{3 \times 21.1^2 \times 100}{8}$ = 16530 ft. lbs.

M from road roller = 3990 × 8 = 31920 ft. lbs.

Dead load per lin. ft. on side stringer. (See section.)

Paving, $20 \times 2\frac{1}{4}$		
3-in. plank, $10.1 \times 2\frac{1}{4}$	= 80.3 lbs.	
6 x 8 joist, $5.6 \times 2\frac{1}{4}$		
Steel.....	40.	"
Guard	10.5	"
Walk plank	7.	"
	137.8	"

Then M dead $= \frac{137.8 \times 21.1^2}{8} =$ 7668 ft. lbs.

M live..... = 31920 "

M total ..... = 39588 "

Required S.

Unsupported 21 ft. $\frac{39588 \times 12}{8800} = 54.$

15 in. I @ 42 lbs. has S = 58.9 which use.

Walk stringer 2 ft. apart.

Load, live..... = 100 lbs. per sq. ft.

dead .... 15 " "

Total ..... 115 " "

Total load on stringer = 115 × 2 × 21 = 4830 lbs., use 4 x 14.

For outside stringer with half load, use 3 x 14.

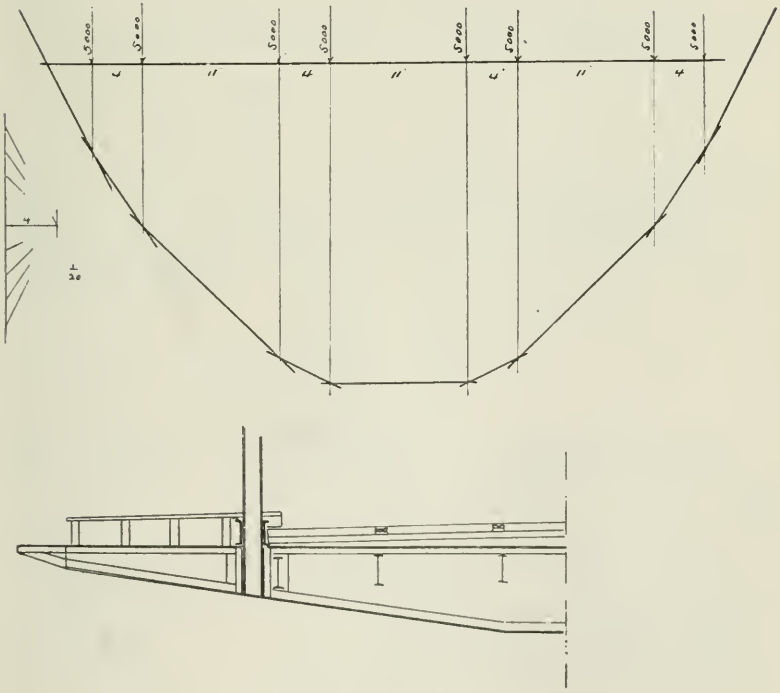


FIG 6.

Floor Beam.

Dead load at I′ = $4\frac{1}{2}$ × 48.7 × 21.1 = 4621 lbs.
" I = 5 × 48.7 × 21.1 = 5137 "

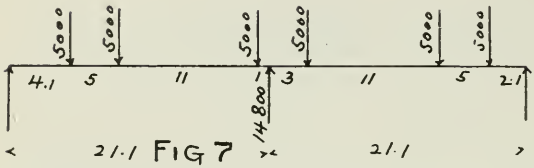


FIG 7

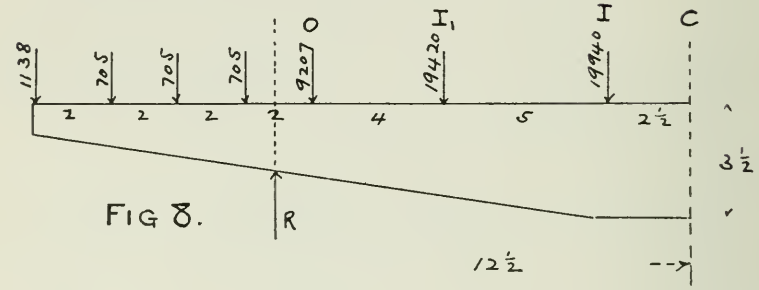


FIG 8.

ft. lbs.

M at O = 1138×8+705×12−51820×1 = 34260
" I_1 = 1138×12+705×24+9207×4−51820×5 = 191700
" I = 1138×17+705×39×9207×9+19420×5−51820×10 = 291413

Max. shear—R O = 48570
O I_1 = 39360
I_1 I = 19940 for 2 tracks.
I_1 C = 9000 for 1 track.

Required flange area at I = $\frac{291413 \times 12}{40.1 \times 10450}$ = 8.34 sq. in. Use 2 Angles 6 × 4 × $\frac{7}{16}$ = 8.36 sq. in. gross.

Required depth at I_1 = $\frac{191700 \times 12}{10450 \times 8.36}$ = 26.2 inches effective.

26.2 + 1.90 = 28.1 back to back.

Bottom flange area will be same as top.

Walk Bracket.

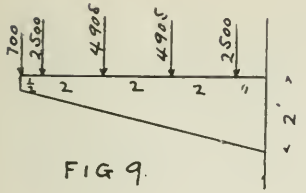


FIG 9.

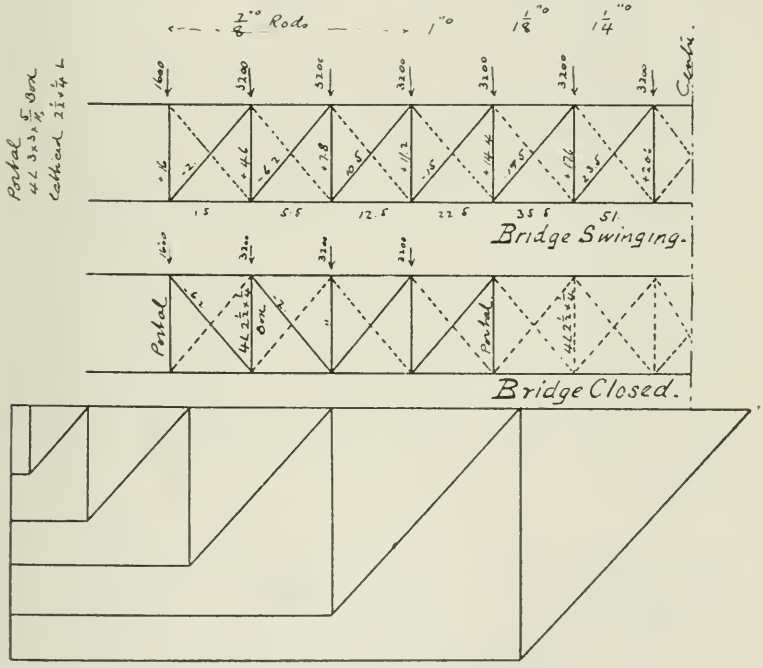
$$M = 2500 \times 1 + 4905 \times 8 + 2500 \times 7 + 700 \times 7\tfrac{1}{2} = 64490 \text{ ft. lbs.}$$

$$\text{Flange stress} = \frac{64490}{1.8} = 35800 \text{ lbs.}$$

$$\text{Flange area required} = \frac{35800}{11400} = 3.14 \text{ square inches.}$$

Use .4 angles $3\tfrac{1}{2} \times 2\tfrac{1}{2} \times \tfrac{5}{16}$, $\tfrac{1}{4}$-in. web plate.

Top Laterals.



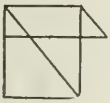


FIG 10.

Bottom Laterals.

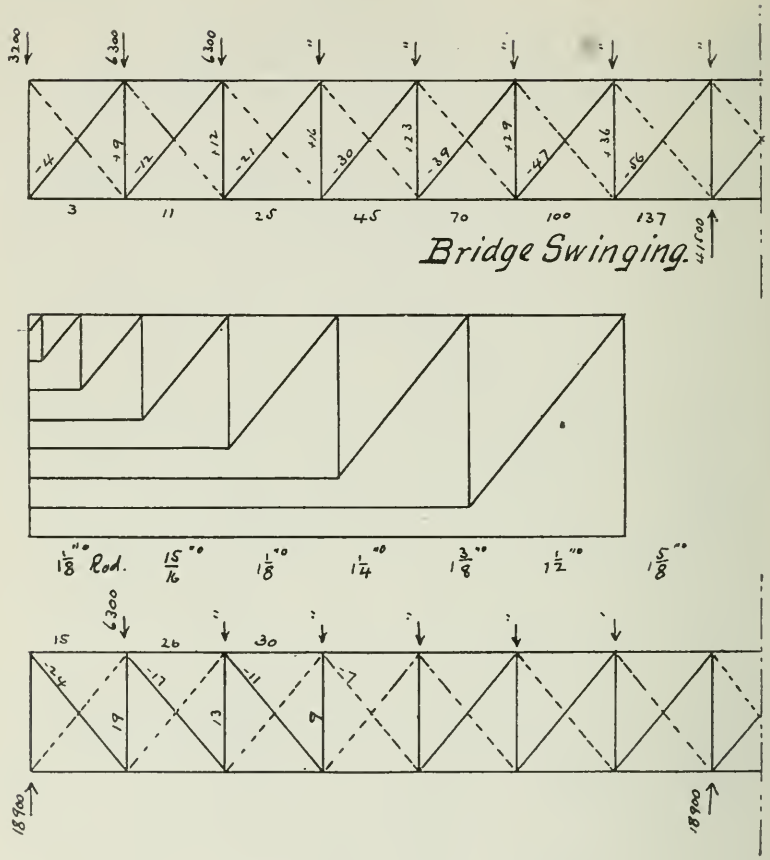


FIG 11.

Weight of Laterals (Half Span).

Upper—

6 rods	⅞-in. x 35 ft. long	420
2 "	1-in. x 35 "	189
2 "	1⅛-in. x 35 "	238
3 "	1¼-in. x 35 "	440
		——1287

Lower—

4 rods	$1\frac{1}{8}$-in. x 35 ft. long	476
2 "	$1\frac{5}{16}$-in. x 35 "	161
2 "	$1\frac{1}{4}$-in. x 35 "	294
2 "	$1\frac{3}{8}$-in. x 35 "	350
2 "	$1\frac{1}{2}$-in. x 35 "	420
3 "	$1\frac{5}{8}$-in. x 35 "	735
		——2436

Sways—

8 rods	1-in. x 26 ft. long	
4 "	30 "	
4 "	32 "	1628
4 "	37 "	
8 "	$1\frac{1}{4}$-in. x 35 "	1176
		——2804

2 Portals—

8 angles	3 x 3 x $\frac{5}{16}$ x 27 ft.	1317
24 angles	$2\frac{1}{2}$ x $2\frac{1}{2}$ x $\frac{1}{4}$ x 6 ft.	
24 "	" " 3 ft.	885
	Details	600
		——2802

4 Top Struts—

16 angles	$2\frac{1}{2}$ x $2\frac{1}{2}$ x $\frac{1}{4}$ x 25 ft.	1640
	Details	680
		——2320

4 Portal Brackets—

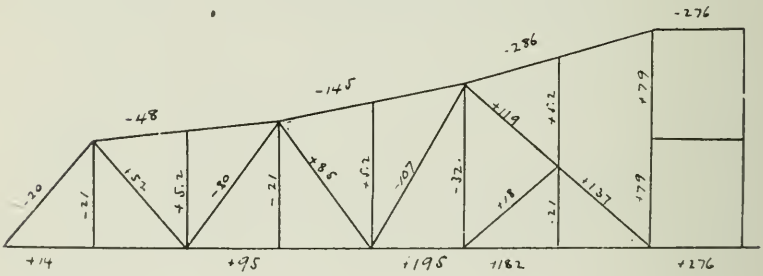
8 angles	3 x 3 x $\frac{1}{4}$ x 8 ft	320
8 angles	$2\frac{1}{2}$ x $2\frac{1}{2}$ x $\frac{1}{4}$ x 3 ft.	
4 "	" " 4 ft.	160
	Details	320
		—— 800

6 Sway Struts—

24 angles	$2\frac{1}{2}$ x $2\frac{1}{2}$ x $\frac{1}{4}$ x 24 ft.	2361
	Details	1020
		——3381

Dead weight per lineal foot of bridge—

Paving 23½ ft. wide 4 in. thick @ 5 lbs. =	470
3-in. plank 23½ ft. wide @ 3½ lbs. =	236
6 x 8 wood joist @ 3½ lbs. =	131
Rails, 80 less 28 paving	52
Walk plank, 17 ft. x 2 in. thick, ½-in. open joints,	114
2 guards, 6 x 6	21
6 joist, 4 x 14 on walk	98
2 " 3 x 14 "	24.5
Hand rail	60
Steel stringers	264
Floor beams	140.8
Lateral system	100.2
Stringer bracing	18.7
Trusses (assumed)	750.
Total dead weight per lineal ft. =	2479.



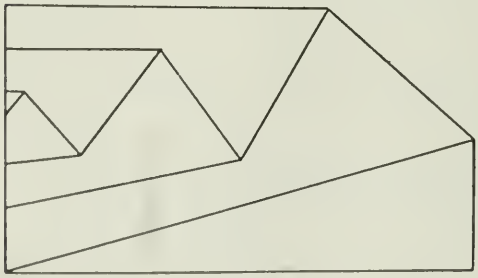


FIG 12

Trusses.

Assume the following cases for loading:

(1) Dead load, ends simply touching supports
(2) Live load symmetrical, continuous girder, 4 supports } Combine.

(3) Dead load, simple span
(4) Live " " " } Combine.

Case 1.—Dead load, per foot of bridge = 2,479 lbs.
" " " panel, per truss = 26,200 lbs.

Case 2.—Live load symmetrical, continuous girder, four supports.

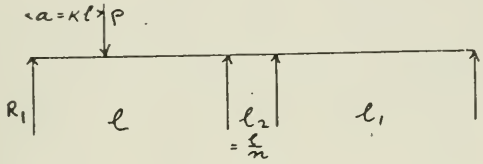


FIG 13.

$$R1 = \frac{P}{H}\left\{H - (H + 2n + 2n^2)K + (2n + 2n^2)K^3\right\}$$ where $H = 3 + 8n + 4n^2$

Live load per lineal foot of bridge = 3,300 lbs.
" " " panel per truss = 34,800 lbs.

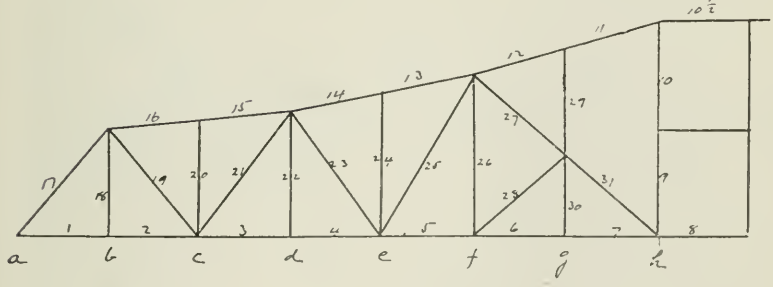
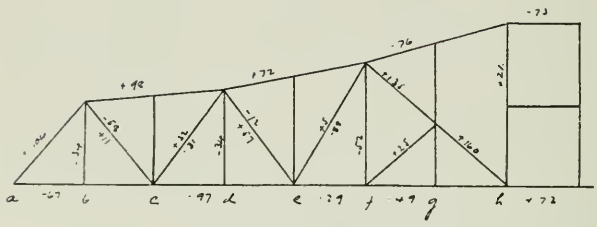


FIG 14

Max. Reaction R1 :

Loads at b c d e f g	2.293	× 34800	= 79800
c d e f g	1.494	× "	= 52000
d e f g	.888	× "	= 30900
e f g	.461	× "	= 16000
f g	.191	× "	= 6650
g	.049	× "	= 1700



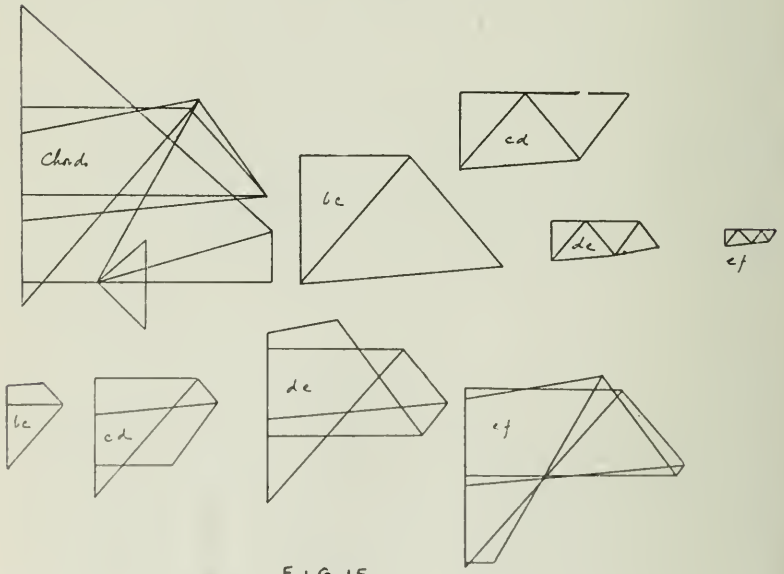


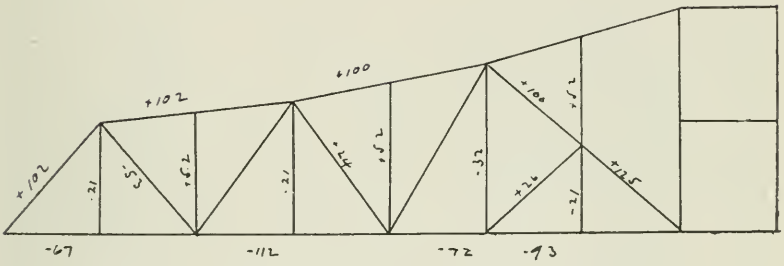
FIG 15.

Max. Reaction R1 :

Loads at b	.799	× 34800	= 27800
b c	1.405	× "	= 48900
b c d	1.832	× "	= 63700
b c d e	2.112	× "	= 73500
b c d e f	2.244	× "	= 78100
b c d e f g	2.293	× "	= 79890

Case 3.—Each arm single span. Dead load.

Dead load per foot of bridge = 2479 lbs.
" " panel per truss = 26200 lbs.



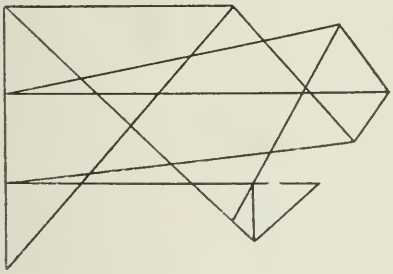


FIG 16.

Case 4.—Each arm single span. Live load.

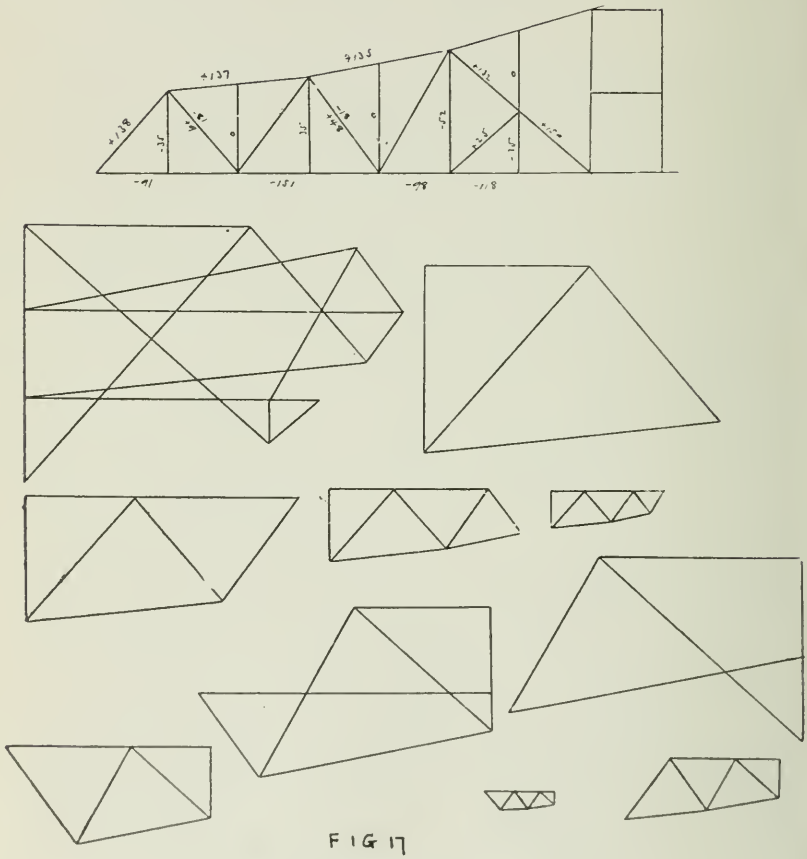


FIG 17

TABLE OF STRESSES.

Member	Case 1.		Case 2.		Case 3. Combine these.		Case 4. Combine these.		Combined. Max. Stresses +	Combined. Max. Stresses —
1	+ 14			— 67		— 67		— 91	14	158
2	+ 14			— 67		— 67		— 91	14	158
3	+ 95			— 97		—112		—151	95	263
4	+ 95			— 97		—112		—151	95	263
5	+195			— 29		— 72		— 98	195	170
6	+182			— 49		— 93		—118	182	211
7	+182			— 49		— 93		—118	182	211
8	+276		+ 73			o		o	349	
9	+ 79		+ 21			o		o	100	
10	+ 79		+ 21			o		o	100	
10½		—276		— 73		o		o		349
11		—286		— 76		o		o		362
12		—286		— 76		o		o		362
13		—145	+ 72		+100		+135		235	145
14		—145	+ 72		+100		+135		235	145
15		— 48	+ 98		+102		+137		239	48
16		— 48	+ 98		+102		+137		239	48
17		— 20	+104		+102		+138		240	20
18		— 21		— 34		— 21		— 34	o	55
19	+ 52			— 58		— 53	+ 9	— 81	63	134
20	+ 5 2		o		+ 5·2			o	5	
21		— 80	+ 32	— 32	+ 17		+ 51	— 27	68	111
22		— 21		— 54		— 21		— 34		55
23	+ 85		+ 57	— 12	+ 24		+ 48	— 18	142	18
24			o	o	+ 5·2			o	5	
25		—107	+ 5	— 88		— 52	+ 8	— 78	8	195
26		— 32		— 52		— 42		— 52		84
27	+119		+135		+100		+132		254	
28	+ 25		+ 25		+ 21		+ 25		50	
29	+ 5.2		o		+ 5.2			o	5	
30		— 21		— 34		— 21		— 34		55
31	+137		+160		+125		+159		297	

Proportioning Members.

No. 1 and 2 + 14000, - 158,000.

For alternate tension and compression unit =

$$11700\left\{1 - \frac{\text{max. less}}{2 \text{ max. greater}}\right\} = 11200 \text{ lbs.}$$

$$\left.\begin{array}{l}\text{From dead weight of member.}\\ \text{Stress per sq. in. on outer fibre.}\end{array}\right\} = \frac{21 \times 50 \times 21 \times 12}{8 \times 42 \times 3} = 260.$$

Allowable unit = 11200 − 260 = 10940 lbs.

Required sectional area = $\frac{158000}{10940}$ = 14.4 sq. in.

Use 2 channels 12 in. @ 25 lbs. = 14.7 sq. in. gross.

No. 3 and 4. Stresses are + 95000 and − 263000.

For alternate tension and compression unit = 9734

Less for dead weight 270

9464 lbs. per sq. in.

Required sectional area = $\frac{263000}{9464}$ = 27.7 sq. in.

Use 2 channels 12 in. @ 30 lbs. = 18 sq. in. gross.

2 Pls. $11\frac{3}{4} \times \frac{3}{8}$ - - - - - = 9 " "

Total - - 27 " "

No. 5. Stresses are + 195000 and − 170000.

For all compression unit is $13750 - 707\frac{l}{r}$, where $\frac{l}{r} = \frac{21}{4.2} = 5$.

Hence " " " = 10215 lbs.

From dead weight of member, stress per sq. in. on outer fibre = $\frac{21 \times 90 \times 21 \times 12}{8 \times 52 \times 3}$ = 470 "

Allowable for direct compression - - = 9745 " per sq. in.

For alternate tension and compression unit =

$$11700\left\{1 - \frac{16600}{2 \times 180000}\right\} = 6282$$

From dead weight unit = 380

Total allowable unit - 5902

Required sectional area = $\frac{195000}{5902}$ = 33.1 sq. in. gross.

Use 2 channels 12 in. @ 35 = 21 sq. in. gross.

2 plates $11\frac{3}{4} \times \frac{1}{2}$ 12 " "

33 " "

No. 6 and 7. Stresses are + 182000 and - 211000

For all compression unit = 10200

Less from dead weight 400

9800

For alternate tension and compression unit =

$$11700\left\{1-\frac{165000}{2\times 204000}\right\}=6973 \text{ lbs.}$$

Less from dead weight 400 "

6573 "

Required sectional area $=\frac{211000}{6573}=32.1$ sq. in.

Use 2 channels 12 @ 35 = 21 sq. in. gross.

2 plates $12\times\frac{1}{2}$ 12.5 " "

33.5 " "

Dead, live and wind for No. 6 + 282000 and − 281000

" " " " " " 7 + 319000 and − 311000

Unit for above = 6573 + (50% of 6573) = 9858

282000 ÷ 9858 = 28.6 sq. inches } both of which are less than

319000 ÷ 9858 = 32.4 " " } for dead and live only.

No. 8. Stress is 349000 lbs.

For all compression, 2 square ends, unit =

10800 lbs. per sq. in.

Less from dead weight = 400 " " " "

10400 " " " "

Required sectional area $=\frac{349000}{10400}=33.5$ sq. in.

Use 2 channels 12 in. @ 35 lbs. = 21 sq. in.

2 plates $12\times\frac{1}{2}$ 12 " "

Total - - 33 " "

No. 9. Stress is + 100000 lbs.

$\frac{l}{r}=\frac{24}{3.5}=7.1$ Unit $=13750-642\frac{l}{r}=9130$ lbs.

Required sectional area $=\frac{100000}{9130}=10.6$ sq. in.

Use 2 channels 10 @ 20 lbs. = 12 sq. in.

No. 10 is same as No. 9.

No. 10½ Stresses – 349000 and – 260000.

Unit stress for all tension = $11{,}700 \left\{ 1 + \frac{\text{min.}}{\text{max.}} \right\} =$

$$11700 \left\{ 1 + \frac{260{,}000}{349{,}000} \right\} = 20830 \text{ lbs.}$$

Required sectional area – $\frac{349000}{20830} = 16.6$ sq. in.

Use 4 bars $4\frac{3}{4} \times \frac{7}{8}$ in. = 16.6 sq. in

No. 11 and 12. Stresses are – 362000 and – 271000.

$$11700 \left\{ 1 + \frac{\text{min.}}{\text{max.}} \right\} = 20840$$

Required area – $\frac{362000}{20840} = 17.3$ sq. in.

Use 4 bars $5 \times \frac{7}{8} = 17.5$ sq. in.

No. 13 and 14. Stresses are + 235000 and – 145000.

For all compression unit = 10800 lbs.
Less from dead weight 400 "

10400

For alternate tension and compression unit =

$$11700 \left\{ 1 - \frac{\text{max. less}}{2\text{max. greater}} \right\} = 8280 \text{ lbs.}$$

Less from dead weight 380 lbs.

7900 "

Required sectional area $\frac{235000}{7900} = 29.6$ sq. in.

Use 2 channels 12 @ 35 lbs. = 21 sq. in.
1 Plate $18 \times \frac{1}{2}$ 9 "

Total 30 "

No. 15 and 16. Stresses are 239000 and – 48300 lbs.
For all compression unit 10400

For alternate tension and compression = 10620
Less from dead weight 400
10220

Required sectional area = $\frac{233000}{10200}$ = 22.8 sq. in.

Use 2 channels 12 @ 30 = 18 sq. in.
1 Plate 18 × $\frac{5}{16}$ = 5.6 "
Total = 23.6 "

No. 17. Stresses are + 240000 and — 20000.
For all compression unit = 8660.

Required area = $\frac{232000}{8660}$ = 26.8 sq. in.

Use 2 channels 12 @ 35 = 21.
1 Pl. 18 × $\frac{3}{8}$ = 6.7
Total - - 27.7 sq. in.

No. 18, 22, 30. Stresses — 55000 and — 19000.

Unit for all tension = $10500\left\{1 + \frac{\text{min.}}{\text{max.}}\right\}$ = 14300 lbs

Required sectional area = $\frac{53000}{14300}$ = 3.7 sq. in.

Use 2 channels 8 @ $11\frac{1}{4}$ = 6.6 sq. in. gross.
4.5 " net.

No. 26. Stresses are — 84000, and — 32000.
Unit for all tension, 14500 lbs.

Required sectional area = $\frac{84000}{14500}$ = 5.8 sq. inches.

Use 2 channels 9 in. @ $13\frac{1}{4}$ lbs. = 8 sq. in.

No. 20 and 24. Stress + 5200. Use 2 [8 @ $11\frac{1}{4}$ lbs.

No. 19. Stresses are + 63000 and — 134000.
Allowable unit = 9160 lbs.

Required sectional area = $\frac{131000}{9160}$ = 14.3 sq. in.

Use 2 channels 9 @ 25 lbs. = 14.7 sq. in.

No. 21. Stresses are + 68000 and — 111300.

Allowable unit = 7830.

Required sectional area = $\frac{111300}{7830}$ = 13.1 sq. in.

Use 2 channels 9 @ 25 lbs. = 14.7 sq. in. gross.

No. 23. Stresses are + 142000 and — 18000.

Unit for all compression = 7950 lbs. per sq. in.

" " alternate tension and compression = 10900

Required sectional area = $\frac{142000}{7950}$ = 17.7 sq. in.

Use 2 channels 12 @ 30 lbs. = 18 sq. in.

No. 25. Stresses are + 8000 and — 195000.

Unit for all tension = $11700\left(1 + \frac{\text{min.}}{\text{max.}}\right)$ = 14620 lbs.

Required sectional area = $\frac{195000}{14620}$ = 13.3 sq. in.

Use 4 bars $4\frac{1}{2} \times \frac{3}{4}$ = 13.5 sq. in.

No. 27. Stress = + 254000.

$\frac{l}{r} = \frac{28}{5.6}$ = 5 allowable unit = 10540 lbs.

Required sectional area = $\frac{254000}{10540}$ = 23 sq. in.

Use 2 channels 15 @ 33 lbs.	19.8 sq. in.
1 Plate 18 × $\frac{1}{4}$	4.5
	24.3 " "

No. 31 Stress + 297000.

Required sectional area = $\frac{297000}{10540}$	28.1 sq. in
Use 2 channels 15 @ 33 lbs.	19.8 sq. in
1 Plate 18 × $\frac{7}{16}$	7.9 " "
	27.7 " "

No. 28. Stress = ± 44000.

$\frac{l}{r} = \frac{28}{3.1}$ = 9 allowable unit = 7387 lbs.

Required sectional area = $\frac{44000}{7387}$ = 6 sq. in.

Use 2 channels 8 @ 11¼ lbs. = 6.6 sq. in.

Weight and Quantities in bridge above turntable.

2	Trusses	@ 120140	240280
12	Floor Beams Intermediate	2602	31224
2	" " End	2100	4200
15	Panels Stringer Bracing	394	5910
2	Lines Stringer 15 in. I @ 42		83952
4	" " 15 in. I @ 45		
32	Walk Brackets	368	11776
	Operator's Platform		4384
	Top Laterals		2788
	Bottom Laterals		6635
4	Portals		5560
18	Top Struts		10440
12	Portal Brackets		2400
2	Tower Portals		2780
	Sway Rods		3200
	Ladder		500
28	Railing Posts	48	1400
4	Trolley Poles	514	2056
2	Trolley Struts	738	1476
900	Hook Bolts		700
120	Plain Bolts		360
			422021

90 ft. Gas Pipe Railing
630 ft. Lattice Railing
4 Cast Iron Newel Posts
Wood Joist 11.1 M.
Flooring, etc., 44.9 M.
Wood Block Paving 4 in. deep = 825 sq. yds. = 29700 ft. B.M.

Maximum Stress in Thousands.

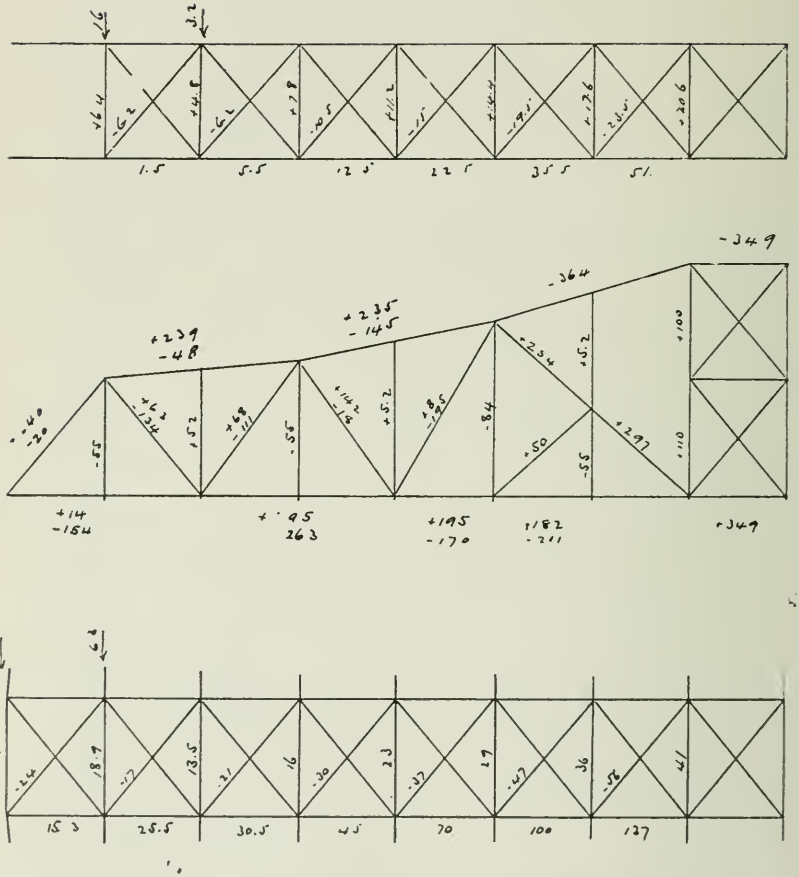


FIG 18.

Diagram of Sizes.

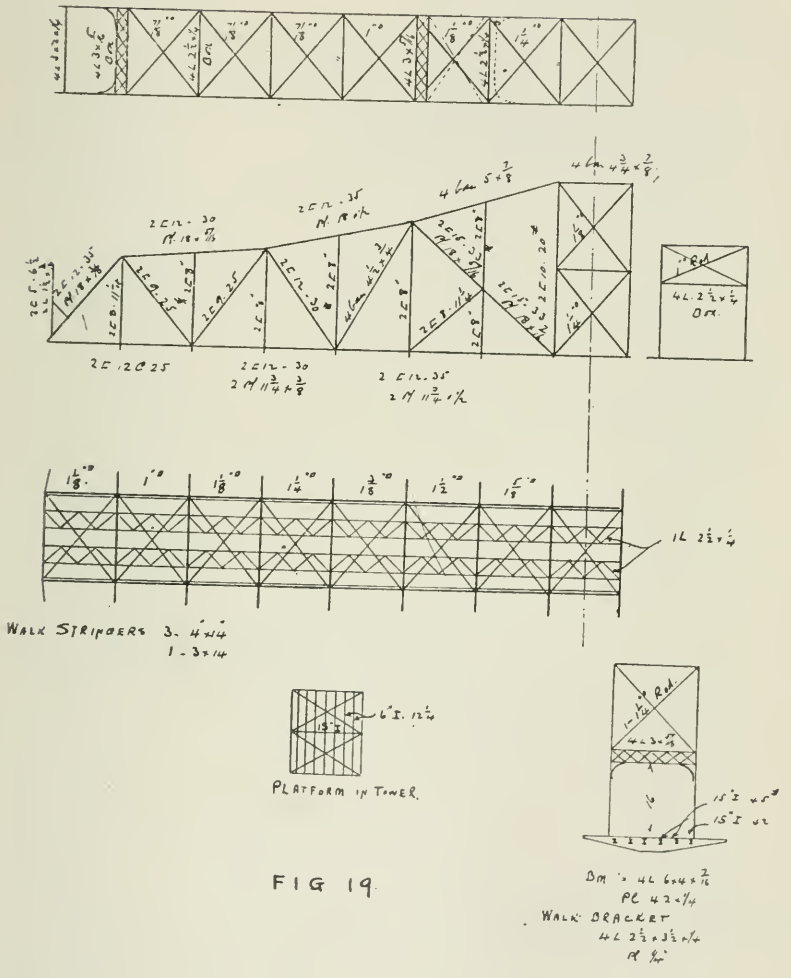


FIG 19.

Trolley Support at End of Draw.

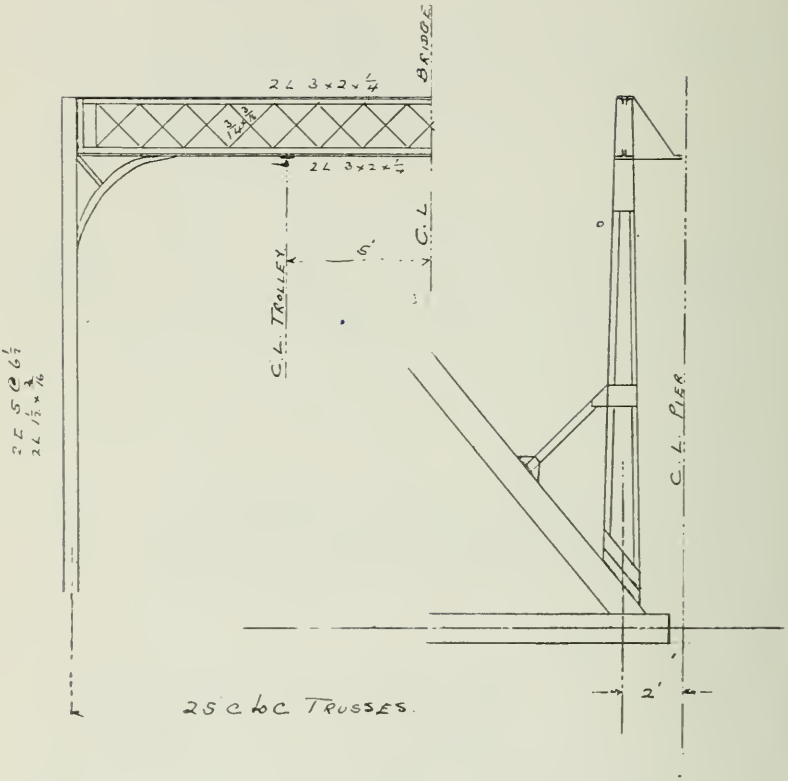


FIG 20.

Drum (Soft Steel) 27 ft. Diam.

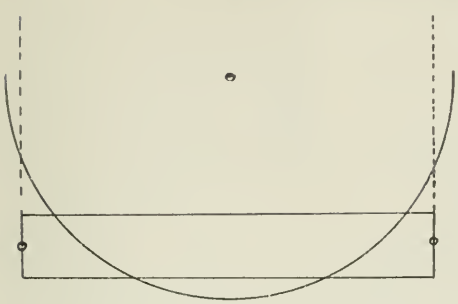


FIG 21

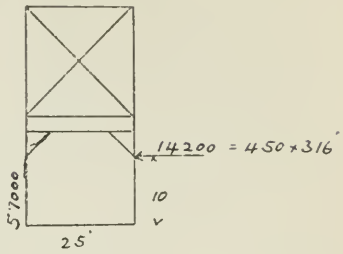


FIG 22.

Max. Load on Drum.	Lbs.
With draw closed.—Live load = 3300 × 168 =	554400
Dead load = 2480 × 316 =	783700
Centre platform	25000
Total load on drum =	1363100
Load on half drum	681600
Wind	57000
	738600
¼ load on drum =	369300
Load on Drum.	
Draw open.—Dead, 2480 × 316	783700
Snow, 800 × 316	252800
Centre platform	25000
	1061500
Load on ¼ drum	265400
Wind	28500
Max. load on ¼ drum =	293900

The above considers 1 foot of snow all over bridge and walk, only when draw is open.

Loading beam distributes ¼ load of bridge on two points about 6 ft. apart.

Consider 3 wheels not bearing. Then Drum is a girder 6 ft. long, with centre Load 135000 lbs.

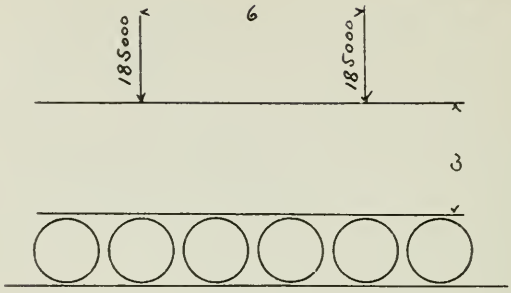


FIG 23.

Hence Required Flange Area is $\frac{92500 \times 3}{3 \times 9000}$ = 10.3 sq. in. net.

Use 2 angles $5 \times 5 \times \frac{1}{2}$ = 8 sq. in. net.
1 Cover Plate $16 \times \frac{1}{2}$ 7

Total 15

Max. Shear 185000 lbs.

Web Area Required = $\frac{185000}{9000}$ = 19 sq. in.

Use Plate $36 \times \frac{1}{2}$ = 18 sq. in.

With stiffeners $4 \times 3 \times \frac{1}{2}$ angles.

Wheels, say 20 in. diameter.

Circumference of Track is about 81 ft. Hence use say 40 wheels.
Allowable pressure on wheels per lineal inch = $600 \sqrt{d}$ live
$1200 \sqrt{d}$ dead

Total Live Load = 554400 lbs.
" Dead " = 808700 lbs.
" Lineal inches required = 554400 ÷ 2680 = 207 inches.
808700 ÷ 5360 = 151 "

Total 358 "

Hence Face of Wheel = 358 ÷ 40 = say 9 in.

Loading Beam (Soft Steel).

Max. load on 1 quadrant of drum = 369300

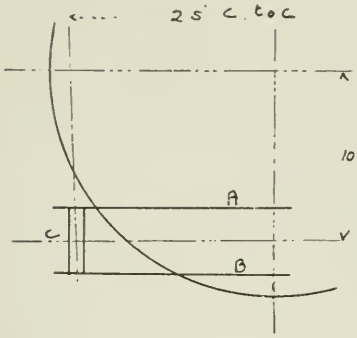


Fig 24

Inside beam A.—

Required flange area $= \frac{369300}{2} \times \frac{2}{2.5 \times 12000} = 12.3$ sq. in.

Use 2 angles $6 \times 6 \times \frac{5}{8} = 12$ sq. in. net.

Web, $30 \times \frac{1}{2}$, reinforced with 2 plates $\frac{3}{8}$ in. thick at ends.

Outside beam B.—

$M = \frac{369300}{2} \times 6$. Assuming beam 30 in. deep, then flange area $= \frac{369300 \times 6}{2 \times 2.5 \times 12000} = 37$ sq. in.

$\frac{1}{6}$ of 2 web plates, $30 \times \frac{5}{8}$	= 6 sq. in.
2 plates, $20 \times \frac{1}{2}$	= 16 "
2 angles $6 \times 6 \times \frac{7}{8}$	= 16 "
	= 38 "

Max. shear = 185000.

Web area = $185000 \div 7000 = 26$ sq. in. Use 2 webs, $30 \times \frac{5}{8} = 26$ sq. in. net.

Girder C.—Flange area required $= \frac{369300 \times 2}{2 \times 2. \times 12000} = 15.5$ sq. in.

Use 2 angles $6 \times 6 \times \frac{3}{4} = 15$ sq. in net.

Shear = 185000. Use 2 pls. $28 \times \frac{5}{8}$.

Turning Gear.

What is the required horse-power to turn bridge?

No wind acting.

From experiments by Mr. A. P. Boller on the new London drawbridge, he deduced the following rule:

H.P. $= \frac{.01wv}{550}$, " w = weight of bridge pounds.
" v = velocity in feet per second at rack.

$$= \frac{.01 \times 973000 \times .67}{550} = 11.8$$

Velocity assumed for end of draw = 6 miles per hour (average).

This turns bridge through 90 deg. in 30 seconds.

Extra power required to open bridge against an unbalanced wind pressure of 5 pounds per sq. ft. on total exposed surface of bridge.

Wind pressure on half bridge (one end) = $15 \times 158 \times 5$.

$$\therefore \text{Thrust at rack} = \frac{15 \times 158 \times 5 \times 158}{13.5 \times 2} = 62400 \text{ lbs.}$$

Length of quadrant = 23.5 ft. $\therefore$ Work done = 62400 lbs. $\times 23\frac{1}{2}$ =ft., lbs. in 30 seconds.

$$\therefore \text{H.P.} = \frac{62400 \times 23\frac{1}{2}}{2 \times 33000} = 22.$$

Total required H.P. = wind	22.
Friction and inertia	11.8
	33.8

Use say 30 H.P. General Electric motor, which will stand overloading to about twice its rated capacity.

Rack. Proportion this for capacity of 30 H.P. motor. Work done on rack $23\frac{1}{2}$ ft. long in 30 sec. = $30 \times 33000 \times 2$.

$$\therefore \text{Thrust on rack} = \frac{30 \times 33000 \times 2}{23.5} = 84000 \text{ lbs.}$$

Assume this thrust of 84000 lbs. resisted by 2 teeth.
42000 " " " 1 tooth.

For cast iron 1200 p. f. = 42000, p. and f. are pitch and face of rack.

Assume face = 9 in. Then pitch = 3.7 in.—circular.

Turning Gear.

Hand lever.

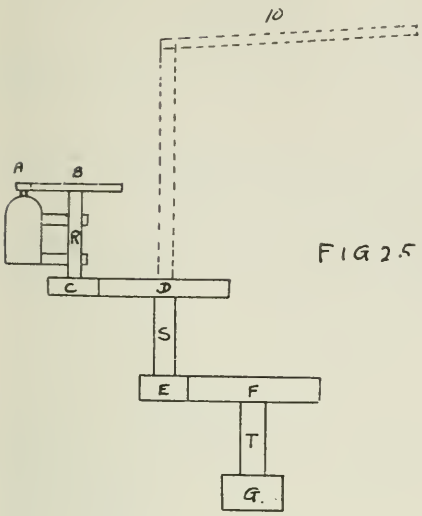


FIG 25

Gears A and B go with motor. A has 14 teeth, and $4\frac{3}{5}$ in. diameter. B has 67 teeth, and $22\frac{1}{3}$ in. diameter. Shaft R is $3\frac{1}{4}$ diameter to fit motor boxes.

Take average speed of motor at 400 revolutions per minute. Then shaft R has 85 revolutions per minute.

If bridge opens in 30 seconds, then speed of shaft T is $11\frac{1}{2}$ revolutions per minute. Therefore required speed reduction is $\frac{85}{11.5} = 7.4$.

Use 2 reductions of 3.7 each.

Then if we assume pinions E and C at 9 in. diameter each, gears D and F will be $9 \times 5.7 = 33.3$ in. diameter.

To proportion teeth, use the following formula: $W = 1200$ p. f. where W = thrust on tooth, p. and f. are pitch and face.

Gears are steel. C and D have $1\frac{1}{2}$ in. pitch, $4\frac{1}{2}$ in. face.
E " F " $2\frac{1}{2}$ " 6 "
G has $3\frac{3}{4}$ in. pitch, 9 in. face, 15 in. diameter.

To proportion shafts, use the following formula for steel:

Diameter $= \sqrt[3]{\frac{T}{2200}}$, where T = tortional moment in inch lbs.

Hence shaft S = $4\frac{3}{4}$ in. diam. Shaft T = 6 in. diam.

Hand Turning Arrangement.

Number of revolutions of pinion required to open draw = $5\frac{1}{2}$ in 30 seconds. Number of revolutions of lever required to open draw = $5\frac{1}{2} \times 3.7 = 20$.

Circumference of walk $= 10 \times 2 \times \pi =$ say 60 feet.

$\therefore$ Distance walked in opening draw $= 60 \times 20 = 1200$ ft.

If man walks $2\frac{1}{2}$ miles per hour, or 240 ft. per minute, then time required to open bridge by hand is $1200 \div 240 = 5$.

Power required with no wind blowing is 11.8 H. P. to open bridge in 30 seconds.

Hence power required to open bridge is 5 minutes $= \frac{11.8}{5 \times 2} =$ 1.18 H. P. $= 1.18 \times 33000 = 38900$ ft. lbs. per minute.

One man can push 50 lbs. on lever while walking. Hence 1 man power $= 240 \times 50 = 12000$ ft. lbs. per minute. Hence number of men required $= \frac{38900}{12000} =$ say 3 men.

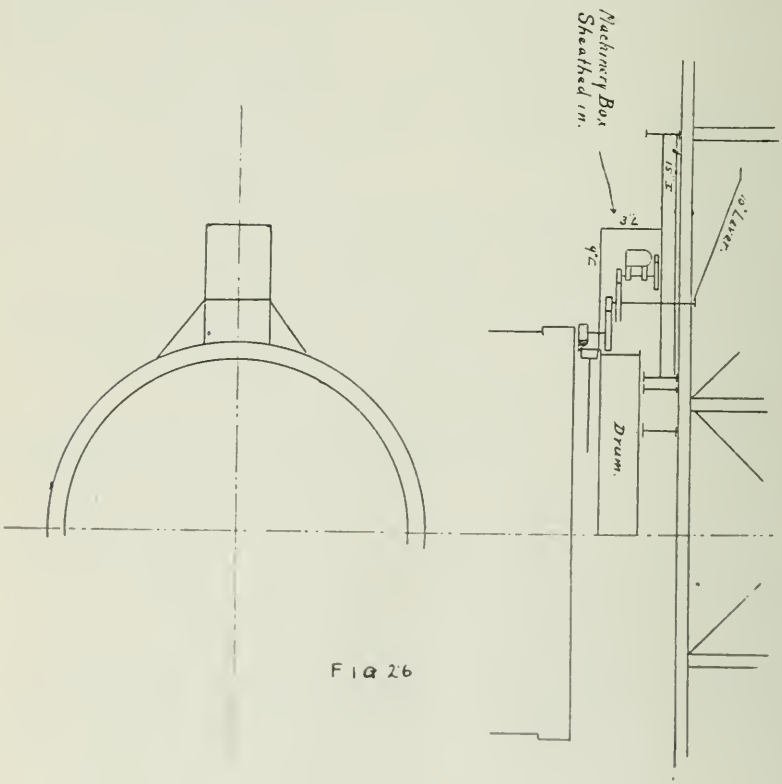


FIG 26

Turn-table.

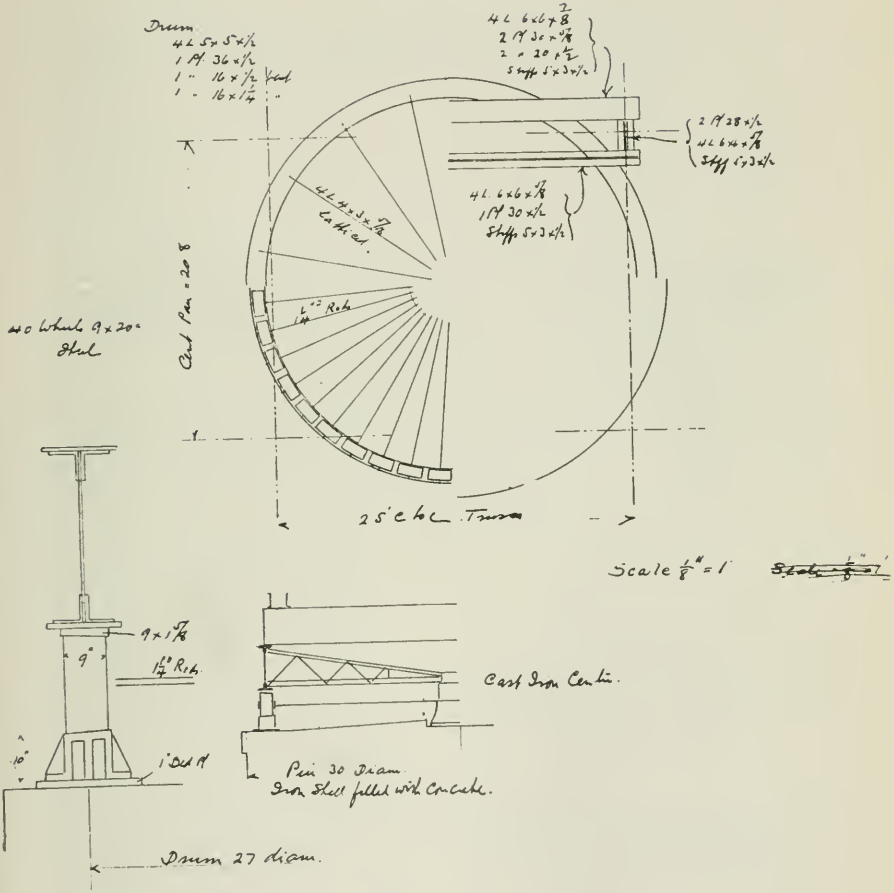


FIG 27

End Lifting Machinery.

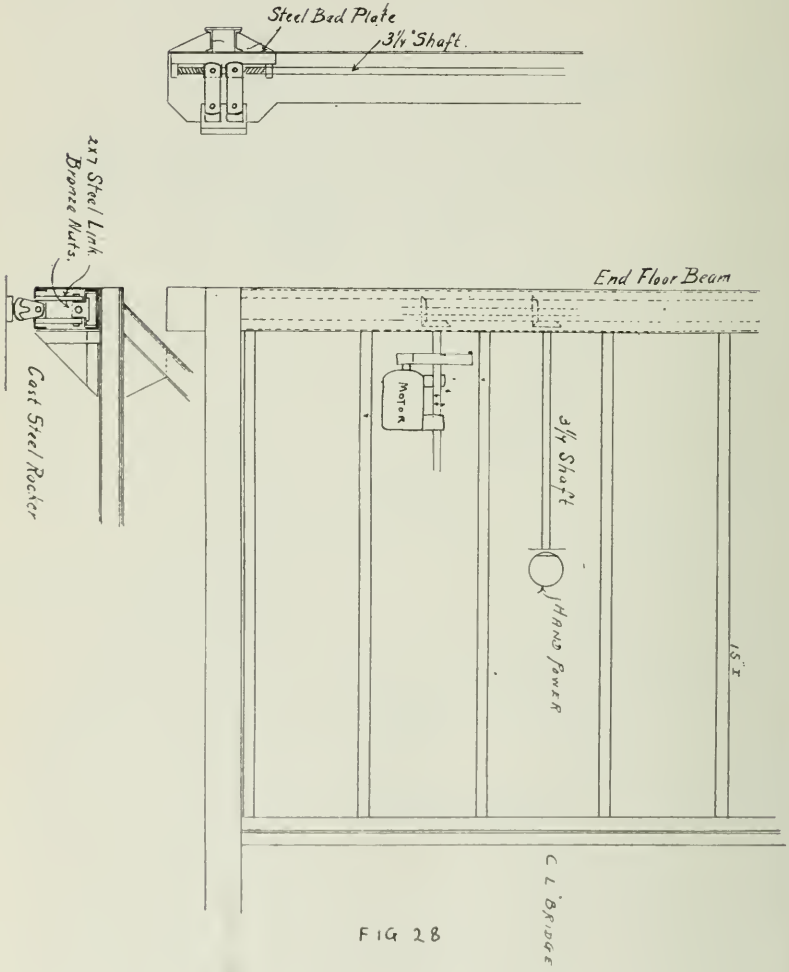


FIG 28

Weight of Turn-table.

2 Loading Beam	16356
2 " "	11218
Drum	20572
16 Drum Struts	9056
Machinery Box	3871
Bed Plates	7288
40 Wheel Rods	1900
$4 \times \frac{1}{2}$ Wheel Bars	1360
2 Centre Discs	1360
4 Loading girders	5644
Wt. of T. T. without machinery	78625
Rack and Track	25500
40 Wheels 20 × 9 in.	18000
Centre Machinery	13900
2 Sets end Machinery	15600
	73000

3 electric motors, 30 H. P. with rigging for operating same.

Besides these, there is required submarine cables, track rails, operator's house in tower, signals, gates, etc.

Summary of Weights.

Bridge proper	338000
" Joist	84000
Turn-table	78600
Machinery	73000

Total wt. of Metal = 573600 = 44 lbs. per sq. ft. of floor and walks.

This weight per sq. ft. of floor agrees very nearly with my formulæ for weight of drawbridges, which is weight per sq. ft. =

$$3 + \frac{\text{Total Span}}{8}$$

The Madison Street Bridge.

7 fixed spans @ 190 - - - -	1330 feet
1 draw span - - - - - -	316 "
Total length - - - - - -	1646 "

HANDLING DAYLIGHT

W. J. Withrow.

It is with extreme pleasure that I have the privilege of standing on this platform once more after the elapse of over a decade.

Prismatic lighting, to the consideration of whose properties I invite your attention this afternoon, is of engineering interest, not so much on account of any abstruse calculations, as for its proved usefulness as a new application of certain well known laws of Optics to the practical lighting with daylight of dark interiors. At the risk of mentioning a good deal that is familiar to you, I will endeavor clearly to outline the general principles governing the use of this light-bending window glass.

As you all know, a light ray travels in a straight line through a uniform transparent medium, such as air at a constant density, but alters its direction on passing obliquely into a medium of different density. This may be well represented by considering a company of soldiers marching on even ground and striking obliquely the edge of a ploughed field. The end of the company entering the soft ground first is held back, while those still on firm ground, keeping up their old speed of marching, swing their end ahead. If the company still marches at right angles to its front it now moves in a new direction, more nearly at right angles to the line of demarcation between the firm and the soft ground. The greater the difference in the ground, the greater the change of direction, and the sharper the angle at which the company strikes the edge of the soft ground the greater the resultant change of direction. On moving from soft ground to hard again the operation is reversed—*i.e.*, the first files out move faster, thus swinging the company around more nearly parallel with the edge of the soft ground. One can easily imagine the company emerging at such a sharp angle that the first files out would swing their end so far ahead as actually to double back into the field. This will be referred to later on when considering total internal reflexion of light.

This, though an unscientific demonstration yet clearly illustrates the fundamental law of Optics, which forms the basis of prismatic lighting, viz.—the sine of the angle of incidence equals the sine of the angle of refraction multiplied by a constant. The particular constant for any two bodies varies with the difference in their relative densities and to a minor extent possibly with their other properties.

In Fig. 1. I, the angle of incidence, is the angle between the incident ray of light i and the perpendicular A Z to the surface

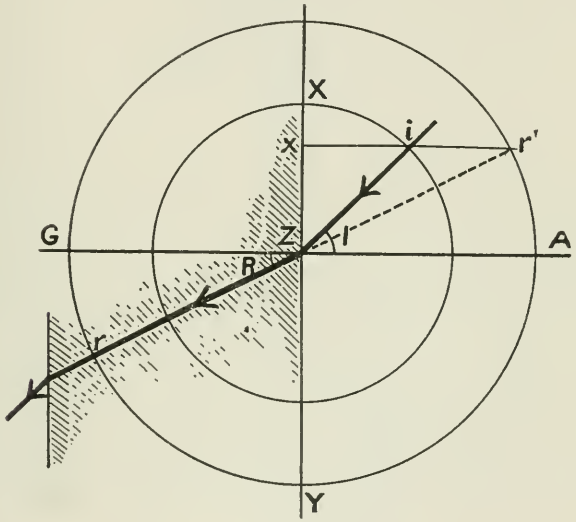


Fig. 1.

X Y of contact between the two transparent media through which the ray passes, and R, the angle of refraction, is the angle between the refracted ray r Z and the same perpendicular A Z G produced.

It is found that for air and flint glass, such as is used in the manufacture of prisms, the constant a equals 1.53, consequently the refractive power of this glass in air may be stated thus—Sin I = 1.53 Sin R.

Or, to express this graphically, see Fig. 1. In the plane X Y, between the body of air A and the body of glass G, at the centre Z, describe two circles X i and Y r at distances relatively of 1 and

1.53. Let i Z be any incident ray of light piercing the plane X Y from the body of air A at the point Z and cutting the circle X i at i. Through i draw x i r′ perpendicular to the plane X Y, cutting the circle Y r at r′ and the plane X Y at x—then r Z r′ produced will be the direction and sense of the refracted ray, i Z A the angle of incidence and G Z r the angle of refraction, and Sin i Z A =1.53 Sin G Z r.

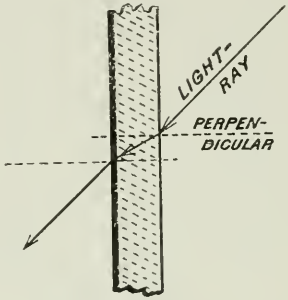


Fig. 2.

A ray of light passing from glass to air would require the constant a to be 1.53, and investigation would show that on passing through a surface parallel to the plane X Y into the air again, the ray would be bent back to its old direction. This is what happens with plate glass, see Fig. 2. If, however, it pass out of the glass through a plane inclined to the first it will assume a new direction, see Fig. 3. This latter is what happens with prisms.

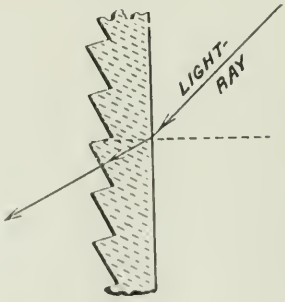


Fig. 3.

If both surfaces were made continuous one edge of the wedge so formed would be very thick, and the whole too heavy for use

in a window, see Fig. 5. One surface of a prism plate is therefore made in a succession of inclined planes forming a series of small wedges instead of one large one. By increasing the angle between the two surfaces of the prism plate the divergence of transmitted

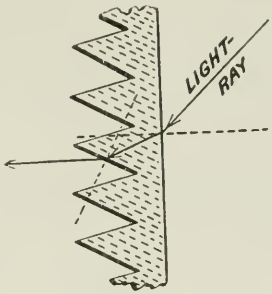


Fig. 4.

light would be increased, see Fig. 4. For this reason prism plates are made with different inclinations varying by 5° in the several plates of the series. These plates are made 4″ square, as larger sizes cannot be sharply moulded, and are strongly glazed together

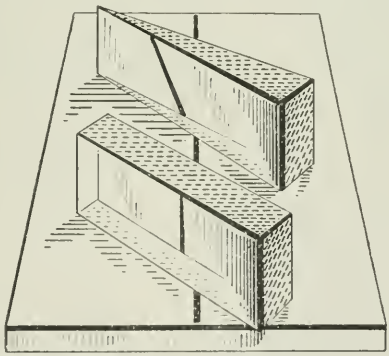


Fig. 5.

in copper by a patented electrolytic process to form large sheets of any required shape.

In order to bend incident light laterally, two complete series of prism plates are manufactured with the prism tilted up, one to the right, and the other to the left, at an angle of 22½°. By placing a right tilted prism on its side, we get a left tilt of 67½°,

asd reciprocally with the left tilt prism. By tilting an ordinary prism plate half way to right or left, we obtain 45° right or left tilts, whereas tilting it completely to right or left we get right or left tilts 90°.

With this range of prism plates and certain cases of using the prisms inside-out, light from any source, falling upon a window, may be directed to any part of the interior.

Having considered the theory of prisms, we will now consider their application.

Stand any place in a room. Look out through the window. The part of the room where you stand is primarly lighted from that particular part of the outside world that you can see. If you see a dark wall, you will be in the dark—if you see a bright sunlit or white washed wall, or generally better still—the open sky, then where you stand will be well lit, if, of course, the window space is large enough for the room.

This primary lighting is more or less modified by light reflected to you from any particularly well lit part of the same room. If a bright sunlit pavement outside throws a strong light on the ceiling near the window, the reflected light therefrom may make the whole room bright. Or, if the sun shines directly through the window for a part of the day, the interior may be rendered light throughout by reflection from the spot on the floor or wall where it shines, or by radiation from a translucent blind or window.

Generally speaking, however, the sky space, as seen from the window, is by far the brightest source of light available for illuminating the interior.

If, as generally happens—particularly in our more congested city districts, the bright sky is cut off by some obstruction opposite the window, such as a building, trees, etc., then the usefulness of prisms comes into play. Here, with ordinary window glass, the bright light from a more or less confined sky-space above falls bright and clear upon the floor immediately inside the window, where it is mainly absorbed by the non-reflecting carpet, dark flooring or furniture, and the rear of the room is left dark and

more or less gloomy, see Figs. 6 and 7. If, now, the window, frequently, merely the upper part, be glazed with prisms of a refracting angle merely sufficient to bend the light from the sky immediately over the top of the building opposite, sending it horizontally or slightly upwardly back through the room, then all the rest of the light from the sky up to the zenith will be spread equally along the rear and side walls and across the floors toward the window, giving an even illumination throughout.

In order to get a satisfactory result in each case, it is, of course, necessary to instal a sufficient area of prisms to suit the size of the room and the available sky space outside.

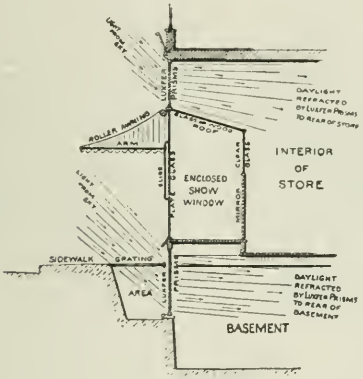


FIG. 6.

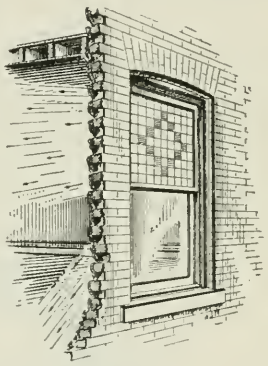


FIG. 7.

Some of the refinements of prismatic lighting which may make or mar its efficiency—I shall now briefly indicate.

If a very high building opposite has a low one, or none at all, close to right or left, then the use of one of the tilted prisms will draw light from the open side, bending it back into the room with greater illuminating effect than could be obtained by drawing light from the narrow band of sky seen over the top of the building. If the space above is extremely narrow, as in narrow lanes between buildings, or in light wells, the light may fall so steeply that the usual vertical window intercepts very little of it. In this case a canopy of prisms is hung outside in front of the upper part

of the window, see Fig. 8. Any of the various forms of prisms mentioned above may be used here if the refracted light is required to be thrown merely a short distance into a room to light desks or other articles near the window. Prisms can only be adapted to refract light up to about 60°, in fact anything beyond 45° of refraction begins to loose in brilliancy.

If, on the other hand, the almost vertically falling light is required to be thrown horizontally back into a room, the principle of refraction will not answer. In this case a form of prism is used in which the light entering the plane surface falls upon an inner

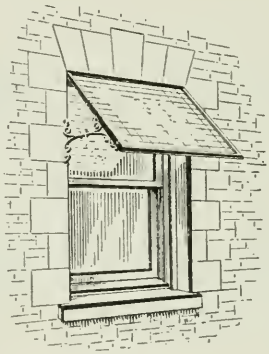


Fig. 8.

surface at such an angle as to cause its total reflexion. This surface will reflect with all the brilliancy of a silvered mirror, throwing the light into the room through the third surface of the prism.

For sidewalks this principle is adopted—the Standard prism, has two unequal downwardly projecting prisms of unequal angle, so adapted as to throw light falling vertically downward inwardly toward the basement—the unequal points being introduced to prevent the reflected light from being stopped by the next prism point in front. See Figs. 9 and 12.

A later and better form is the Multiprism, which has a single downwardly projecting wedge, having its reflecting and inward transmitting surfaces curved so as to cause the light reflected from

the different parts of the surface of one prism to successively pass as close to the bottom of the next prism as possible. These prisms

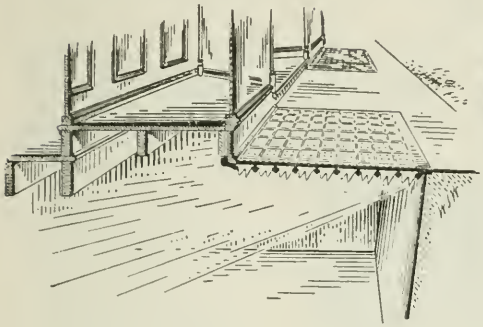


Fig. 9.

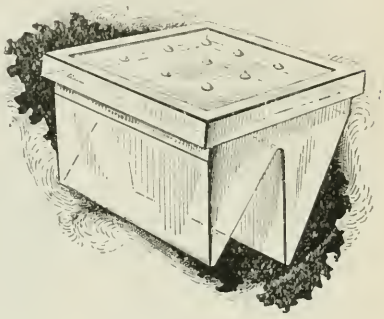


Fig. 12.

are set brick fashion, so as to break joints, and from the basement give the appearance of an unbroken sheet of light. See Fig. 10.

Where a stringer, joist or other inside obstruction on the basement ceiling, prevents the pavement prisms from throwing their light back to the rear of the cellar, a curtain of window

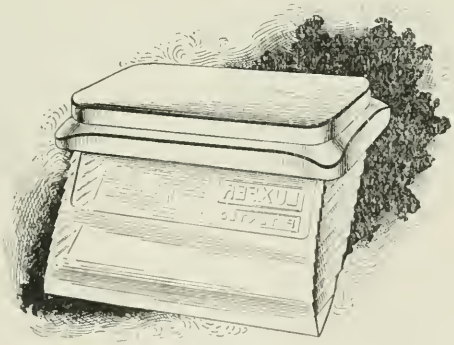


Fig. 10.

prisms of slight refractive power near the top increasing to high refractive efficiency at the bottom, is hung between the pavement prisms and the cellar. This curtain gives a second refraction to the light from the pavement illuminating the whole interior to the rear. This form of curtain works well in open areas where traffic does not necessitate the use of pavement prisms.

All these prism panels, pavement and window, light not merely the space in front of them, but fan-out their light sideways in exactly the same proportion as the sky space from which they derive their light is spread laterally.

In the case of window prisms, if there is a heavy overhang or reveal, the upper prisms would be over-shadowed and useless. In this case the prism panel is either hung in a separate wooden

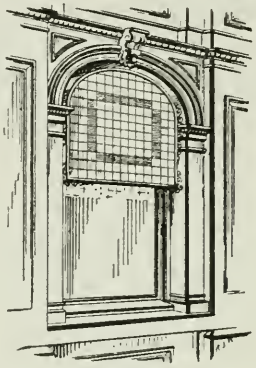


Fig. 11.

or ornamental iron frame out near the front of the wall or cornice, see Fig. 11. A more recent way is to remove the upper part of the window, placing the prisms in a closed frame near the front of the wall, and uniting the bottom of the prisms with the deep-set lower part of the window by a transom bar, in which is installed a ventilating device.

AIR BRAKES.

W. E. Foreman.

The subject of "Air Brakes" is so broad, that to properly describe it, a detailed description of each part, showing the improvements that have been made in each during the last few years ought to be given. But as I am both limited by time and space, a general description of the principal systems now in use is all that can be attempted at present. Besides the general description I would like to bring before you for consideration a few very interesting problems which are closely connected with this subject.

The "Air Brakes" has quite a long history, which forms very interesting and instructive reading. Many different forms of power brakes were in use in the early years of the last century. The most important of these were the "Chain Brake," and the "Hydraulic Brake." Then in the second half of the nineteenth century these were superseded by the "Vacuum" and "Straight Air." And again a few years after the introduction of the above, they in turn were also displaced by the Automatic Vacuum and the Automatic Air Brakes. The latter was invented by Mr. George Westinghouse in the year 1873, just four years after the introduction of the "Straight Air" brake. From year to year the above gentleman patented many improvements upon this latter form until it reached its present form of perfection.

The Vacuum Brake.

The Vacuum Brake, which at one time was the greatest rival the Westinghouse Company had to contend with, but which to-day is nearly extinct as far as this continent is concerned, we will consider just a moment. In principle it is diametrically opposite to that made use of in the Automatic Air Brake. The principle upon which this brake operates is as follows:—The train pipe, which extends the full length of the train, is always kept free of air; and when an application of the brakes is desired, the air at atmospheric pressure is admitted to the train pipe, and sets a valve in such a position that one side of the brake diaphragms is directly

connected to a reservoir from which the air is exhausted. The excess pressure on the other side of the diaphragm which is exposed to the atmospheric pressure, forces the diaphragms forward and applies the brakes. To release the brakes, the air is again exhausted from the train pipe, and the valves and brake diaphragms take or return to their normal positions.

The following apparatus comprise the Automatic Vacuum Brake:—

1. The ejector, the function of which is to maintain the vacuum in the train pipe and brake diaphragms.

2. A continuous train pipe line with hose couplings between each car.

3. Brake diaphragms from which the air is exhausted, causing the pressure of the atmosphere to force the rubber disks into the iron shell and set the brakes.

3. The reservoir, in which a vacuum is maintained, and into which the air is constantly exhausted from the diaphragms.

6. Finally the valve which forms the connection between the reservoirs and the diaphragms. Its objects are to control the passage of air from the brake diaphragms to the reservoir, and partially or wholly apply the brakes.

In Fig. 1, is shown the Eames' Automatic Vacuum Brake, which ranks among the first of this kind.

The "Quick Action Automatic Brake," which is a decided improvement on the previously mentioned "Automatic," was first introduced shortly after the Master Car Builders' braking tests, conducted at Burlington during the year 1887. It is in use on all railroads in America; and in England and the continent it is fast driving its competitors from the market. The Westinghouse Company have equipped by far the largest proportion of trains with their system. The New York Company are second, while the percentage of cars equipped with other systems is so small as to be negligible.

The following general description of the operation of the Air Brake will apply equally as well to the New York Company's as to the Westinghouse, since the apparatus for each system fulfil the same functions and only differ in construction.

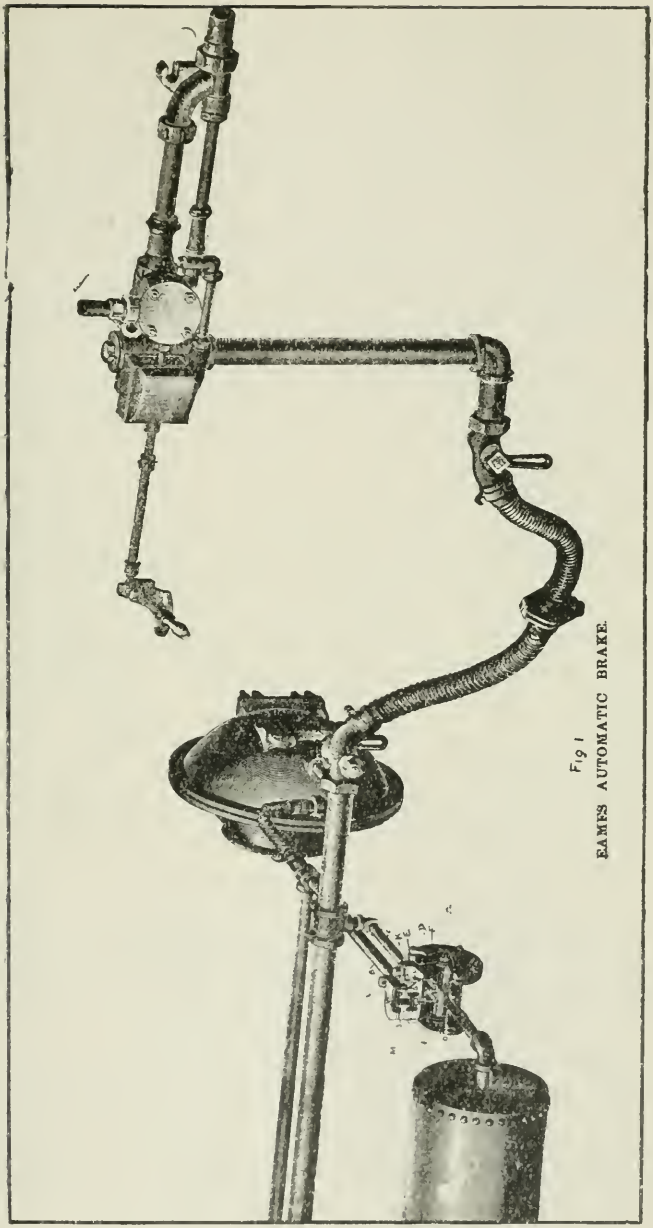


Fig 1
EAMES AUTOMATIC BRAKE.

The air, compressed by the pump, is first delivered into the main reservoir. From there it flows to the engineer's valve; thence through the train pipe to the triple valve on each car, passing through the latter to the storage or auxiliary reservoirs. During normal conditions of running, the train pipe and reservoirs, excepting the main reservoir on the engine, contain air under a pressure of 70 lbs. per square inch. With the engineer's valve, changes of pressure in the train pipe are made, causing the triple valves to operate either to apply or release the brakes.

Moving the handle of the engineer's valve a specified distance permits air from the train pipe to escape, thus reducing the pressure therein. This reduction of pressure operates the sensitive triple valve, which then allows air to pass from the auxiliary reservoir to the brake cylinder, forcing the brake piston in the direction to apply the brakes.

To release the brakes, the engineer's valve is moved back to its running position, and the train pipe pressure is then raised to 70 lbs. per sq. in. This increase in train pipe pressure causes the triple valve to reverse its position, closing the connection between the auxiliary reservoir and the brake cylinder, allowing the air from the latter to escape to the atmoshpere. The brake piston then returns to its running position, and the brakes are thus released.

The Westinghouse and New York Quick Action Automatic Air Brakes consist of the following principal parts:—

1. The compressor or pump which compresses the air.

2. The main reservoir in which the compressed air is stored.

3. The engineer's equalizing and discharge valve, which regulates the flow of air into the train pipe and auxiliary reservoirs for charging the train and releasing the brakes, and from the train pipe to the atmosphere for applying the brakes.

4. The train pipe, which leads from the engineer's valve throughout the train, supplying air to the auxiliary reservoirs.

5. The brake cylinder which has its piston connected to the brake levers, in such a manner that the brakes are either applied or released according as the piston moves in or out.

6. The quick action automatic triple valve, with which each car is equipped. The valve controls the admission of air from the auxiliary reservoir to the brake cylinder, the discharge of air from the brake cylinder to the atmosphere, and the admission of air from the train pipe to the auxiliary reservoir.

7. The auxiliary reservoir, which stores upon each car sufficient air to operate the brakes upon that car.

8. The pump governor, which regulates the supply of steam to the pump, automatically stopping the supply or steam when the pressures in the train pipe and reservoirs have reached the desired point.

9. The hose couplings, which connect the train pipe of one car to the train pipe of the next.

10. The duplex air gauge, which indicates on one scale the pressure in the train pipe, and on the other the pressure in the main reservoir.

11. The conductor's valve, which is operated by that individual when he wishes to apply the brakes.

Westinghouse High Speed Brake.

The Westinghouse High Speed Brake is another form or modification of the Automatic just described, and which is used on trains which run at very high speed, such as the "Empire State Express" and "Congressional Limited." This brake consists of the quick-action, with the addition of an automatic pressure reducing valve. One of these valves is connected to each brake cylinder, and the air pressure supplied to the train pipe and auxiliary reservoirs considerably increased. In ordinary service application the valve remains inoperative, unless the pressure in the cylinder exceeds a certain fixed limit (usually sixty pounds), when it then operates to discharge air from the cylinder until the fixed limit is again reached, and then ceases to discharge air from the cylinder. The reason for this variation of the brake cylinder pressure, is that at high rates of speed greater pressure can be exerted on the wheels without causing them to skid, than can be exerted on wheels revolving at a low velocity. Consequently, as the speed of the train is materially reduced, the pressure in the

brake cylinder has also been reduced. We have thus increased the retardations during the early part of the stop, while running no danger of skidding the wheels. Trains can be stopped by this brake, when they are running at the rate of sixty miles an hour, in about 450 feet shorter distance than when they are equipped by the ordinary Quick Action Automatic Brake.

The triple valve is the most important link in the whole air brake system. On it we depend for the rapidity of the application of the brakes. If, for one short instant it fails to operate, when required, the brakes on that car are inoperative.

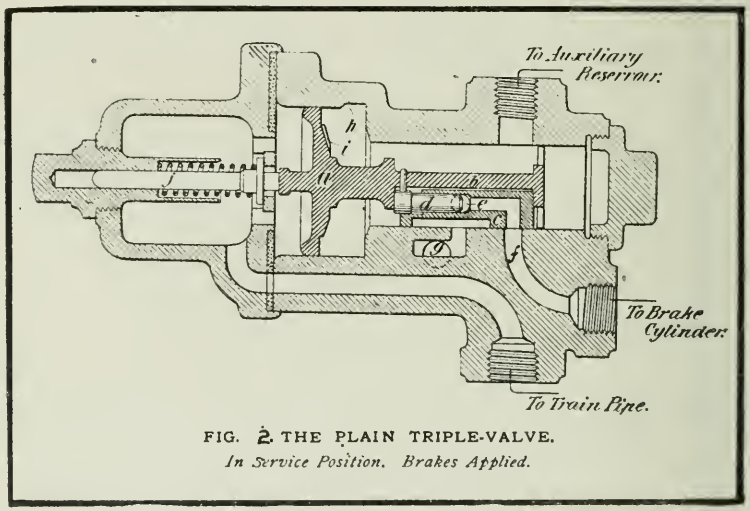


FIG. 2. THE PLAIN TRIPLE-VALVE.
In Service Position. Brakes Applied.

The triple valve has undergone many changes and improvements before it reached its present forms. The first valve was invented by Mr. George Westinghouse, Jr., in 1872, and the last shortly after the Burlington tests in 1887.

Before describing the valve we must understand why they are called triple valves. It performs the triple function of (1) Admitting air from the train pipe to the reservoir, for the purpose of charging it with air under pressure. (2) Admitting air from the reservoir to the brake cylinder, for the purpose of applying the brakes, and (3) Establishing communication between the

brake cylinder and the atmosphere for the purpose of discharging the air from the brake cylinder and releasing the brakes.

There are two Westinghouse Triple Valves, the plain Automatic, which is used in ordinary service applications, and the Quick Action Automatic, which is designed both for service and emergency applications. This latter valve is simply a plain triple

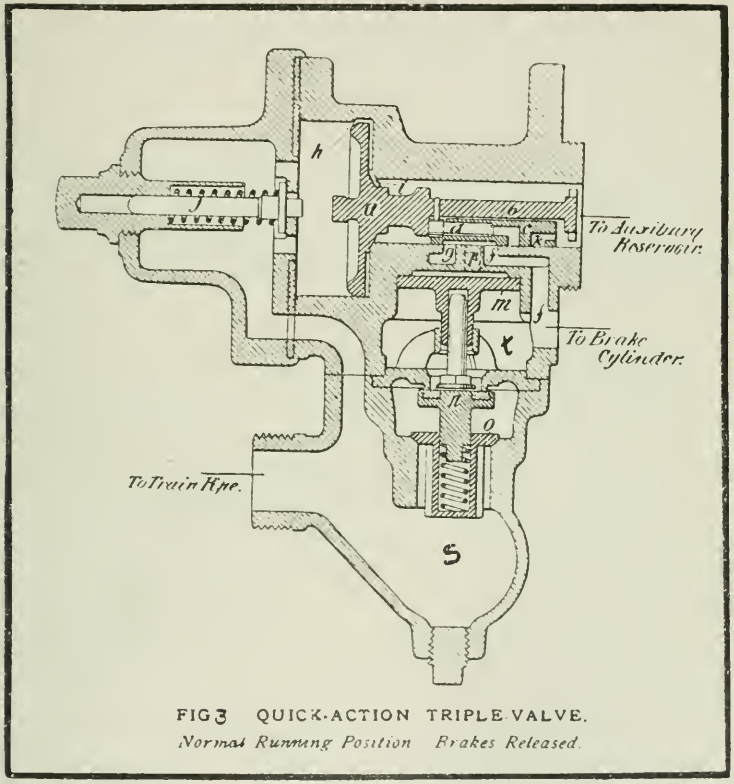


FIG 3 QUICK-ACTION TRIPLE VALVE.
Normal Running Position Brakes Released.

with the addition of a few more valves which render it more efficient in emergency applications than the plain triple.

Fig. 3 is a drawing of the Westinghouse Quick Action Automatic valve, with its parts in the normal running position with brakes released. If the part p, and the chambers below it, s and t, were removed, the valve would be transformed into a plain triple.

The emergency parts of this valve are then, the chambers s and t, the piston m, and the valves n and o. The locations of the pipe connections to the train pipe, the auxiliary reservoir, and the brake cylinder are clearly indicated. A piston, a, is adapted to move backward and forward, while its stem, b, extends forward into a somewhat smaller valve chamber containing a slide valve c, which is loosely confined between two shoulders upon the piston stem. In the interior of the slide valve c, is a small poppet valve, d, called the graduating valve, which is secured by a pin to the piston stem b.

In the position of the parts shown in fig. 3, the compressed air from the train pipe enters through the passage ways and chamber on the outer side of piston a (to the left). Then it passes around the piston, through the feed grooves h and i into the valve chamber, from which it passes directly to the auxiliary reservoir. This reservoir is thus kept charged with air at the same pressure as the train pipe line.

When the engineer makes a service application, he reduces the train line pressure about five pounds by discharging a portion of the air. This lessens the pressure upon the outer face of the piston a, and the excess pressure upon the other side forces the piston to the left, at the same time closing the feed grooves h and i, thus cutting off all communications with the train pipe, and simultaneously withdraws the graduating valve d, from its seat in the slide valve. The shoulder at the end of the piston stem b, then comes in contact with the end of the slide valve c, which is thereafter moved along with the piston in its outward progress, which is finally arrested by contract with the stem j. Then the part e is over the passageway f, and the air from the auxiliary reservoir has a clear passage to the brake cylinder. The part e extends transversely through the slide valve and conducts air from the auxiliary reservoir into the passageway in the slide valve, which has now been uncovered by the outward movement of the graduating valve d. The discharge of air from the auxiliary reservoir to the brake cylinder is accompanied by a reduction of the air pressure in the auxiliary reservoir and the valve chamber of the triple valve, which continues until the pressure is slightly lower

than that of the air remaining in the train pipe, and at the chamber at the outerside of the piston a. The slight preponderance of pressure on the outside of the piston causes it to move inwardly until the graduating valve d becomes seated in the slide valve. The piston is prevented from moving any further by the frictional resistance offered by the slide valve and its seat. Upon the closing of the graduating valve d, communication between the brake cylinder and the auxiliary reservoir is shut off, and the brakes remain applied with so much force as is due to the compressed air which has already been admitted into the brake cylinder.

If the engineer finds that he needs more braking force, he makes a further slight reduction in the train pipe, and the above operation is again repeated, admitting a further quantity of compressed air to the brake cylinder. This operation is called graduating, and entirely depends upon the proper working of the graduating valve d.

The above description applies both to the plain and the quick action triples in service stops. In an emergency application of the quick action triple a considerable quantity of air is discharged from the train pipe, causing a great difference between the pressures on the sides or faces of the piston a. This preponderance of pressure on the inner face of the piston causes the piston a to travel outwardly with more force, compressing the spring on the stem j, until it is arrested by the end of the chamber. The passageway p, which admits the compressed air above the piston m, being thereby uncovered, instantly conducts the compressed air from the auxiliary reservoir to the upper face of the piston m, which forces that piston downward and thereby opens the emergency valve n, as shown in Fig. 4. It is to be observed that at this instant, (1) the brake cylinder is empty, no air from any source having yet entered it; (2) the air pressure in the train pipe, while having been reduced considerably below the pressure in the auxiliary reservoir is still great, and has, by merely lifting the valve o, a capacious and unobstructed passageway, around the emergency valve n, into the empty brake cylinder. Thus the air from the train pipe lifts the check valve o, and rushes into the brake cylinder, until the pressure in the brake cylinder and the train

pipe are equalized. Then the check valve closes, shutting off all connections between the train pipe and the chamber t. The air which has been admitted to the brake cylinder, increases the available braking force which may be obtained in the brake cylinder.

The effect of the discharge of air from the train pipe into the brake cylinder of the first car does not merely more quickly

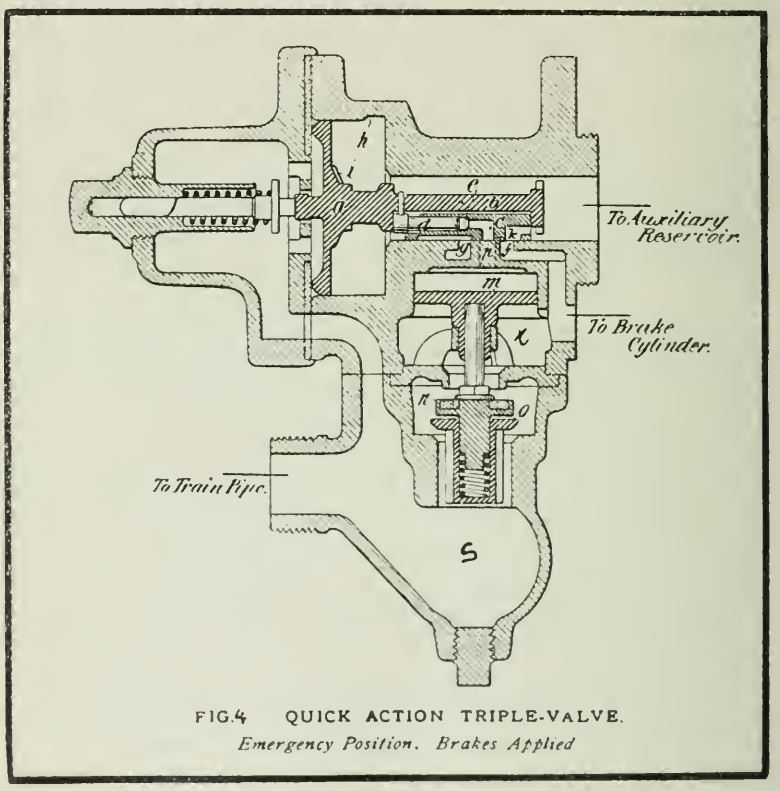


FIG. 4 QUICK ACTION TRIPLE-VALVE.
Emergency Position. Brakes Applied

and powerfully apply the brakes on that car, but also causes a sudden and material reduction of the pressure upon the outer face of the piston a, on the next car. Thus the action which is described above is greatly accelerated on the whole train, the first triple hastening the action of the second, and the second the action of the third, etc., throughout the whole train.

To release the brakes with both styles of triple, the train pipe is recharged to its normal pressure, which preponderance of pressure on the outer face forces the piston a, to its running position. At the same time the slide valve c, is carried to its position for running, as shown in Fig. 3, where a direct connection is made from the brake cylinder, through the passageway f, and exhaust port g, to the atmosphere. Thus the air being exhausted from the brake cylinder the brakes are released.

New York Triple.

The New York Air Brake have also both a plain triple and quick action triple. Like the Westinghouse they are both automatic in their action.

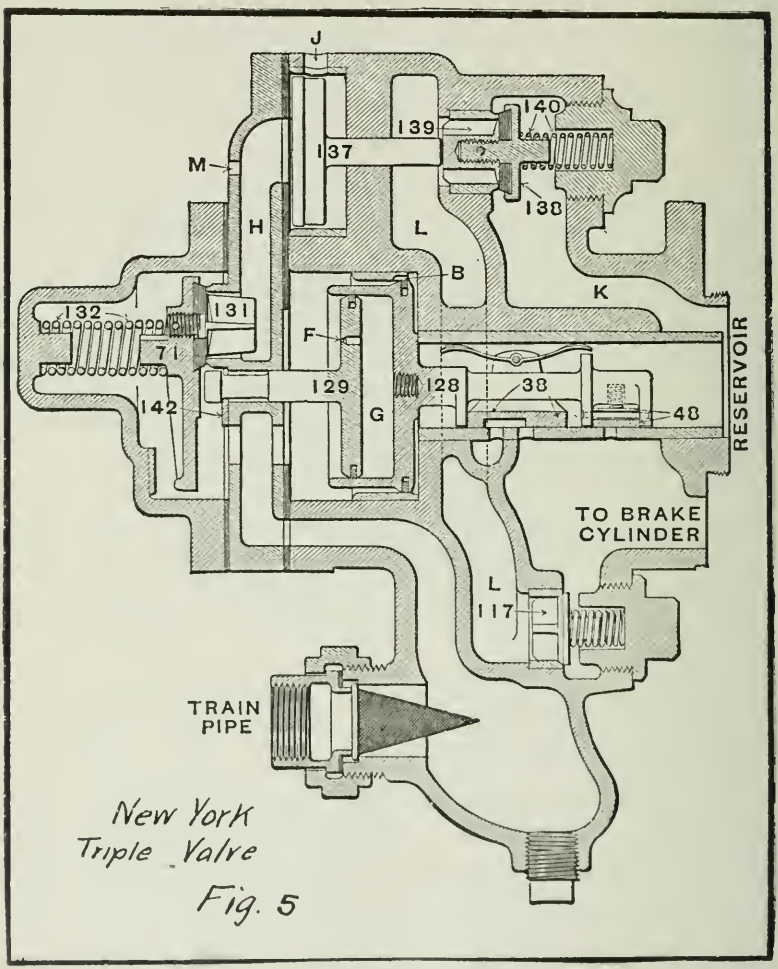
The quick action triple is shown in Fig. 5. The quick action parts occupy the left and top portions of the drawing, and remain inoperative under ordinary service applications. The service parts occupy the central portion of the drawing, the operation of these parts can be traced on the drawing which clearly indicates them.

"Referring to the figure, the vent valve 71 is held to its seat by spring 132, assisted by train pipe pressure, and can only be opened when piston 129 is forced to the left. Quick action valve 138-139 is held to its seat by spring 140, assisted by the reservoir pressure, and can only be opened when piston 137 moves to the right."

"Main piston 128 has the same stroke both for emergency and service applications, but is extended to form a cylinder in which piston 129 is fitted. Through piston 129 is a small opening F, allowing the train pipe air to pass through and equalize the pressure on both sides. The dimensions of this opening are such that when the main piston 128, moves slowly to the left, as in service applications, the air in space G will be forced through opening F without disturbing piston 129 from its position shown."

"A sharp reduction of train pipe pressure for an emergency stop will cause main piston 128 to move rapidly to the left. In this case air from space G cannot flow through passage F fast enough, and exerts a momentary pressure upon piston 129, strong enough to overcome its resistance and cause valve 71 to be forced

from its seat. This allows train pipe air to enter the passage H and escape to the atmosphere through holes J and M, while at the same time, it forces piston 137 to the right, which unseats valve 139 and allows the full power of the reservoir pressure



to be instantly effective in the brake cylinder through the large passageways K, L, and check valve 117."

"Meanwhile, as passage F is always open, the temporary pressure exerted by the air in chamber G, has rapidly lost its

effect, and spring 132 has returned valve 71 to its seat, thus stopping the escape of air when train pipe pressure is sufficiently reduced to properly apply the brakes. As valve 71 closes, it returns piston 129 to its original position. Valve 139 and piston 137 have also been returned to their former positions, as shown in the figure."

"Restoring the train pipe pressure causes the valves 38 and 48 to return to their normal positions as shown, allowing the auxiliary reservoir to be recharged, and the air to escape from the brake cylinder, thus releasing the brakes."

"The astonishing and almost inconceivable rapidity of the serial recurrence of quick-action triple value operation may be best appreciated by comparison with the rate of propagation of simple vibrations through a clear and quiescant atmosphere. The simplest illustration is that of sound, which, under ordinary conditions, travels at the rate of about 1,100 feet per second. The propagation of a sound disturbance to a distance of 2,000 feet in a quiet atmosphere, requires little more than 1.8 seconds. An emergency application of the brakes upon a fifty car train, wherein one piece of mechanism is caused to operate, thereby producing an impulse, which causes a second piece of mechanism to operate, and so repeated through fifty mechanisms with successive impulses, is serially propagated throughout the 2,000 feet in 2.5 seconds."

The increasing use of heavy and high speed cars in street car service, seems to make the application of the air brake even to single cars, a logical necessity. Under present conditions the manual labor and careful attention required by the hand-brake is so great, that the motormen are not able to retain control of their cars and make the most efficient stops. The principle of the air brake has been successfully adapted to the street cars.

The great difficulty in applying this style of brakes was the securing of compressed air. The air was finally compressed in two ways, first by attaching an eccentric, which worked an air compressor, to the axle of the car, and second by installing on the motor-car a rotary air pump driven by a motor. In the first

method about forty revolutions of the car wheels suffices to fill the reservoirs with air, at a pressure of 32 pounds. Having attained that pressure, a governor automatically cuts off in such a manner that the piston stops working against pressure. The motorman applies the brake by simply turning the controlling valve, which allows the air to enter the cylinder. Only three pounds of the storage pressure are required for each application. When the brakes are released and the car starts again, the piston once more operates against pressure to restore the reservoir pressure to 32 pounds; but by an automatic device this does not begin until the car has gathered headway. Then only five revolutions are required to recharge the reservoir to its normal pressure.

In the second method or system the running of the air pump and the maintenance of the reservoir at the desired pressure is entirely independent of the speed of the car. The pump is driven by a motor which is supplied with electricity from the trolley wire. The current to the motor is automatically turned on or shut off as the reservoir pressure drops below or attains the desired pressure. Besides the motorman has control of the current supply to the motor if desired.

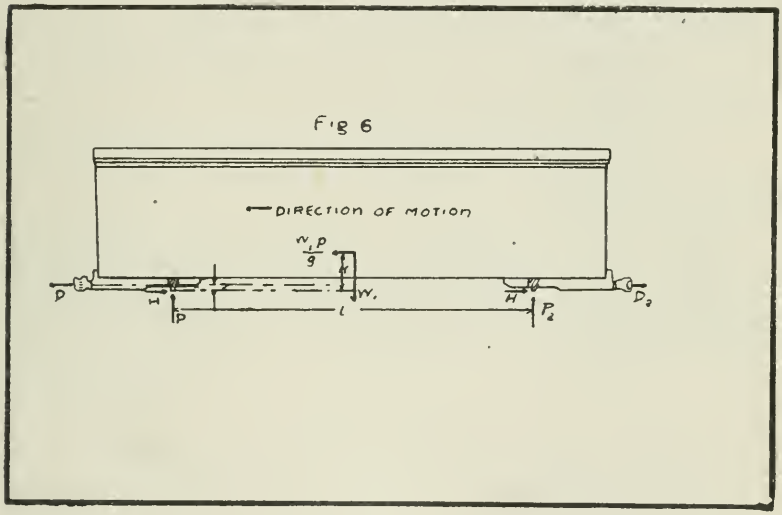
An important subject or division of this topic, is the relations which exist between the various forces which are brought into existence by an application of the brakes. Some of the problems which we will now discuss, bearing on this subject, are: first, the transfer of weight from the rear to the front truck during an application of the brakes; second, the transfer of a certain percentage of the weight borne by each pair of wheels of a four wheel truck when unbraked, from the rear to the front wheels when the wheels are braked; third, the relation between the brake shoe friction and the rail friction; fourth, the proper angle at which to hang the brake shoes, so that the brake shoe pressures may approach, as near as possible, those theoretical relations or values which we will determine in Problem I.

These problems were first discussed by Mr. R. A. Parke, who read a paper before the New York Railway Club in 1897, giving his views and solutions of the foregoing problems. He thus proceeded to consider and solve Problem I.

PROBLEM 1.

To determine the proportionate weight which each truck sustains during an application of the brakes.

We will represent the car with its trucks removed by Fig. 6. The force which each truck exerts upon the car body is indicated by an arrow. This force must be exerted through the centre plate of each truck. In this case we are considering only the case where the brake shoes are hung from the trucks. Brake shoes are so seldom hung from the car body that their discussion is not very profitable.



Let P_1 = the supporting force from the forward truck, which is of course the same as that portion of the weight of the car body which is born or carried by that truck.

P_2 = the supporting force from the rear truck.

H = the retarding force exerted upon the car body, through the centre plates, to reduce the energy of the car body due to its velocity and slacken its speed. We assume that the braking force applied to each truck is the same.

D_1 = the pull upon the draw bar. This quantity is generally a positive quantity when the car is empty and braked to its full

capacity and a locomotive attached ahead. Sometimes this force may become negative when the cars ahead push back upon the draw bar, or the unbraked cars in the rear are pushing this braked car into those ahead.

D_2 = the backward pull on the rear draw bar. This may be a positive quantity due to the action of the cars ahead or may be negative due to the action of the cars behind.

W_1 = the weight of the car body, acting through the centre of gravity of the car body.

l = the distance from centre to centre of the trucks.

k = the distance the centre of gravity is vertically above the point of contact of the truck and the car body.

z = the distance the centre line of the draw bar is above the point of contact of the car body and the truck.

g = the acceleration of gravity.

p = the negative acceleration or retardation due to an application of the brakes.

Now the forces acting upon the car in a horizontal direction are D_1, D_2 and the two forces H. Therefore the total effective resistance to the forward motion of the car body is $2H + D_2 - D_1$. Each particle of the car is subjected to a retardation p, and thus the total retarding force is equivalent to the mass of the car body multiplied by p, or an imaginary force $\frac{W_1}{g}p$, acting through the center of gravity of the car. The energy of the car due to its velocity is opposed to the retarding force $2H + D_2 - D_1$; and thus the force $\frac{W_1}{g}p$ is equal and of opposite sign to the retarding force, and their algebraic sum is zero. That is

$$2H + D_2 - D_1 = \frac{W_1}{g}p\ ;\ \text{or}\ H = \frac{W_1}{2g}p + \frac{D_1 - D_2}{2}. \qquad (1)$$

Taking the algebraic sum of the moments of the forces, real and imaginary, about the point of intersection of the forces H and P, at the front centre plate,

$$P_2 l + (D_1 - D_2)z + \frac{W_1}{g}pk - W_1\frac{l}{2} = 0,$$

From which we get

$$P_2 = \frac{W_1}{2} - \frac{W_1}{g}\,\frac{k}{l}\cdot p - (D_1 - D_2)\,\frac{z}{l}. \qquad (2)$$

Similarly by taking moments about the point of intersection of the forces H and P_2 at the rear center plate we get,

$$P_1 = \frac{W_1}{2} + \frac{W_1}{g}\,\frac{k}{l}\cdot p + (D_1 - D_2)\,\frac{z}{l}. \qquad (3)$$

Now, $D_1 - D_2$ can never be a negative quantity. And z, even if it is negative, is always very small. Therefore from the two equations for P_1 and P_2, it is evident that the sustaining force P_1 is always greater that the sustaining force P_2 during an application of the brakes. Or that portion of the weight of the car body supported by the forward truck during an application of the brakes is greater than that supported by the rear trucks.

Therefore to avoid skidding the wheels, consideration of the rear truck which bears the least weight is only necessary. This brings us to the second problem, namely the conditions which prevail on the rear truck during an application of the brakes. To simplify our calculations we will let the algebraic difference $D_1 - D_2 = D$. Then the force with which each truck retards the car body is

$$H = \frac{W_1}{g}\,p + \frac{D}{2}. \qquad (4)$$

Also substituting the value D for $D_1 - D_2$ in equation (2) we get

$$P_2 = \frac{W_1}{2} - \frac{W_1}{g}\,\frac{k}{l} - \frac{D}{2}\,\frac{z}{l}. \qquad (5)$$

which is the portion of the weight of the car body carried by the rear truck during an application of the brakes.

Problem II.

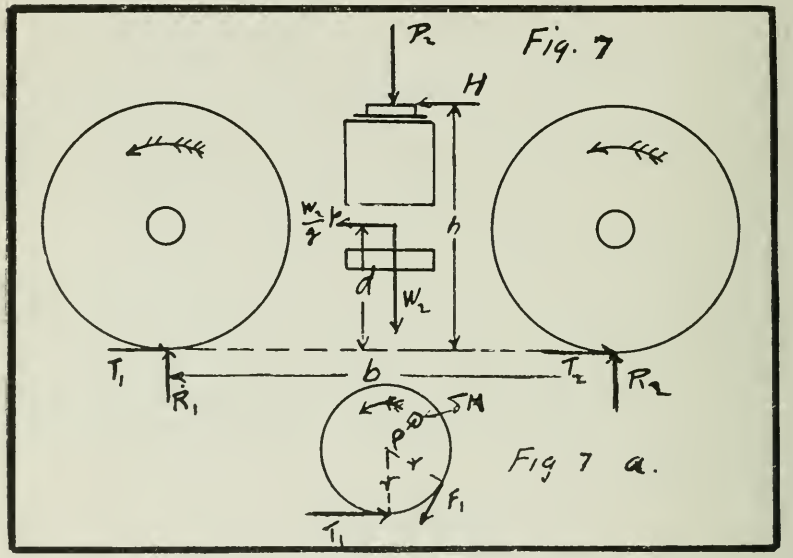
To determine the conditions existing at the rear truck during an application of the brake.

The skeleton of the truck is shown in Fig. 7. The various forces which act on the truck are indicated, and defined as follows:—

R_1 = the pressure of the forward pair of wheels on the rails.

R_2 = the pressure of the rear pair of wheels on the rails.

T_1 = the retarding frictional force applied by the rails to the forward pair of wheels, and keeps up their continued rotation in spite of the friction of the brake shoes.



T_2 = the retarding frictional force applied by the rails to the rear pair of wheels, and keeps up their continued rotation in spite of the friction of the brake shoes.

P_2 = the pressure of the car body upon the rear truck. We obtained the value of this in Problem I.

H = the force with which the car body drags the truck forward. This we also obtained in Problem I.

h = the distance between the point of contact of the car body and the truck, and the top of the rail.

d = the distance the center of gravity is above the top of the rail.

b = the base of the truck.

W_2 = the weight of each complete truck.

Each particle of the truck suffers a retardation p, and the total retarding force absorbed by the truck is equal to the mass of the truck multiplied by p or $\frac{W_2}{g}p$. And this imaginary force acts at the center of gravity of the truck in opposition to the retarding forces, and must be the equivalent of the difference between the sum of the retarding forces $T_1 + T_2$ and the force H which urges the truck forward. Thus,

$$T_1 + T_2 - H = \frac{W_2}{g}p \ldots . \qquad (6)$$

Now taking the algebraic sum of the moments of the real and imaginary forces, first about the point of contact of the rear pair of wheels and the rails, we get

$$Hh + W_2\frac{b}{2} + P_2 b + \frac{W_2}{g}pd - R_1 b = 0.$$

Then taking moments about the point of contact of the forward wheels and the rails we derive—

$$Hh - W_2\frac{b}{2} - P_2\frac{b}{2} + \frac{W_2}{g}pd + R_2 b = 0.$$

Substituting in the last three equations the values of H and P_2 already determined, the equations become respectively:—

$$T_1 + T_2 - \frac{W_1}{2g}p - \frac{D}{2} = \frac{W_2}{g}p,$$

$$\frac{W_1}{2g}ph + \frac{D}{2}h + W_2\frac{b}{2} + \frac{W_1}{2}\frac{b}{2} - \frac{W_1}{g}\frac{k}{l}p\frac{b}{2} - D\frac{zb}{12} + \frac{W_2}{g}pd - R_1 b = 0,$$

$$R_2 b + \frac{W_1}{2g}ph + \frac{D}{2}h + \frac{W_2}{g}pd - W_2\frac{b}{2} - \frac{W_1}{2}\frac{b}{2} + \frac{W_1}{g}\frac{K}{l}\cdot p\cdot\frac{b}{2} + D\frac{z}{l}\cdot\frac{b}{2} = 0.$$

From the first of these equations

$$p = \frac{2T_1 + 2T_2 - D}{W_1 + 2W_2}g. \qquad (7)$$

Again, substituting in the second and third of the above equations the value of p and collecting similar terms, we get—

$$\frac{W_1\left(h-\frac{bk}{l}\right)+2W_2d}{W_1+2W_2}(T_1+T_2)+\left\{\frac{W_1\left(\frac{bk}{l}-h\right)-2W_2d}{W_1+2W_2}+h-\frac{bz}{l}\right\}\frac{D}{2}$$
$$+(W_1+2W_2)\frac{b}{4}-R_1b=0.$$

$$R_2b+\frac{W_1\left(h+\frac{bk}{l}\right)+2W_2d}{W_1+2W_2}(T_1+T_2)+\left\{h+\frac{bz}{l}-\frac{W_1\left(h-\frac{bk}{l}\right)+2W_2d}{W_1+2W_2}\right\}\frac{D}{2}$$
$$-(W_1+2W_2)\frac{b}{4}=0.$$

Solving these equations for R_1 and R_2 respectively, substituting for $W_1 + 2\ W_2$, the complete weight of the car, body and two trucks, the term W,

$$R_1=\frac{W}{4}+\frac{W_1\left(\frac{h}{b}-\frac{k}{l}\right)+2W_2\frac{d}{b}}{W}(T_1+T_2)+\frac{W_1\frac{k-z}{l}+2W_2\left(\frac{h-d}{b}-\frac{z}{l}\right)}{2W}D$$

$$R_2=\frac{W}{4}-\frac{W_1\left(\frac{h}{b}-\frac{k}{l}\right)+2W_2\frac{d}{b}}{W}T_1+T_2-\frac{2W_2\left(\frac{h-d}{b}+\frac{z}{l}\right)-W_1\frac{k-z}{l}}{2W}D.$$

R_1 and R_2 are the pressures of the forward and rear wheels upon the rails, when T_1 and T_2 are the retarding frictions exerted upon the wheels by the rails, and D is the algebraic difference of the pulls on the forward and rear drawbars.

Now the co-efficient of $T_1+ T_2$ in each of the last two equations, is under all conditions of ordinary service a positive quantity. Therefore, the sign before each second term remains unalterable. Again the co-efficient of D is also a positive quantity and the algebraic sign of the last term is unalterable. Under certain conditions the value of the co-efficient of D in the last equation, becomes very small, but does not become negative. When D is zero the last terms disappear. The car is then free and braked to its full capacity. In this case it is evident that R_1 is larger than R_2. And the sign of co-efficient of D remaining unalterable R_1 is evidently greater than R_2. Therefore we conclude that

under any conditions when the brake shoes are applied with the same pressure to each pair of wheels, the rear pair are the most liable to slide upon the rails; and thus the maximum brake shoe pressure should be so designed that the rear pair of wheels will not slide when the brakes are applied.

Now the greatest pressure upon the rails of the forward pair of wheels which at all times and under all circumstances may be depended on for rail friction to cause continued rotation of the wheels, is when D = O.

$$R_1 = \frac{W}{4} + \frac{W_1\left(\frac{h}{b} - \frac{k}{l}\right) + 2W_2\frac{d}{b}}{W}(T_1 + T_2). \qquad (8)$$

And under the same conditions R_2 is a minimum when D is a maximum. To determine the maximum value of D, equation 7 may be transformed into the form

$$D = 2T_1 + 2T_2 - \frac{W}{g}p \ldots . \qquad (9)$$

D and p are the only variables in this equation; and D will then be a maximum when p is a minimum. We are justified in assuming that the minimum value of p is zero. Then the maximum value of D is 2 T_1 + 2 T_2. This occurs when the car is pushed forward from a state of rest with the brakes fully applied. Substituting this value of D in the equation for R_2 we get the minimum pressure of the rear pair of wheels upon the rails. The brake shoe pressures must be designed for this.

$$R_2 = \frac{W}{4} - \left(\frac{h}{b} + \frac{z}{l}\right)(T_1 + T_2). \qquad (10)$$

Equations (9) and (10) are the fundamental equations for determining the proper brake shoe pressures for each pair of wheels. The rail frictions T_1 and T_2 which are obtainable to prevent skidding of the wheels are proportional to R_1 and R_2. And the maximum brake shoe pressures upon both pair of wheels are directly dependent on the values of T_1 and T_2.

Of course it is customary to apply the same pressure to the forward as to the rear pair of wheels; but our reasoning shows that a much greater pressure could be applied to the front pair of wheels with no greater danger of sliding.

Problem III.

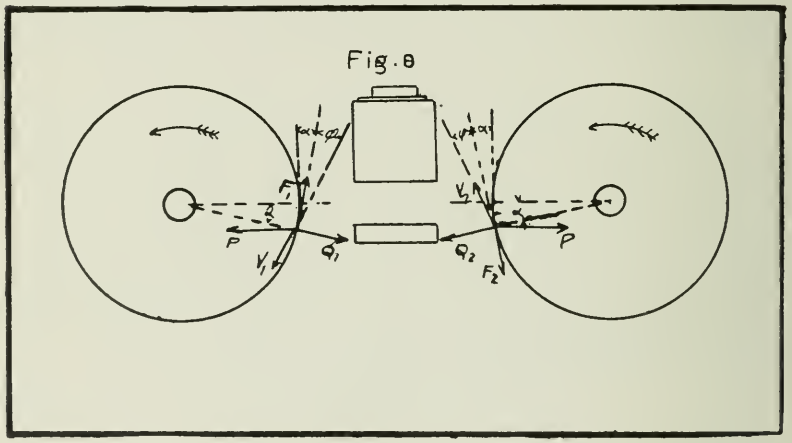
Our next problem is to find the relation between the brake shoe friction and the rail friction; or to determine the maximum safe brake shoe friction upon each pair of wheels.

Let f_1 = the coefficient of static friction between the wheels and the rails.

Then $$T_1 = f_1 R_1, \text{ and } T_2 = f_1 R_2,$$

or, $$R_1 = \frac{T_1}{f_1}, \text{ and } R_2 = \frac{T_2}{f_1}.$$

Let F_1=that friction between the brake shoes and the wheels which is necessary to cause the rail resistance T_1 upon the forward pair of wheels.



F_2= that friction between the brake shoes and the wheels which is necessary to cause the rail resistance T_2 upon the rear pair of wheels.

In Fig. 8 are shown the forces that affect the relation of the forward pair of wheels. T_1 is the frictional force which causes rotation and F_1 is the frictional force resisting rotation, and is caused by the brake shoes. Let r be the radius of the wheel and ρ be the distance of any elementary mass, d M, of the wheels from the center. The retardation at the periphery of the wheels

is the same as that of the car, and the retardation at the distance ρ from the centre is $\frac{\rho}{r}p$.

The force which is exerted on the mass d M to cause a retardation at the rate $\frac{\rho}{r}p$ is d M $\frac{\rho}{r}p$. The friction F_1 must be sufficient to produce this retarding force upon each elementary mass of the pair of wheels, and also to cause the frictional resistance T_1 at the rails. Now taking the algebraic sum of the moments about the center line of the wheels, we get

$$F_1 r - T_1 r - \int dM \frac{\rho}{r} p = 0,$$

or

$$F_1 = T_1 + \frac{p}{r^2} \int dM \rho^2$$

$$= T_1 + M \frac{r_1^2}{r^2} p.$$

In the above equation r_1 is the radius of gyration of each wheel, M represents the mass of both wheels. If w = the weight of each wheel, then $M = \frac{2W}{g}$. From careful calculations it has been found that the square of the radius of gyration is equal to 0.6 times the square of the radius of the wheel. Substituting these values in the above equation,

$$F_1 = T_1 + \frac{1.2w}{g} p \ldots . \qquad (11)$$

Proceeding to consider the rear pair of wheels as we have the forward we obtain for the value.

$$F_2 = T_2 + \frac{1.2w}{g} p \ldots . \qquad (12)$$

The value of p is given in equation (7) where

$$p = \frac{2T_1 + 2T_2 - D}{W_1 + 2W_2} g \qquad (13)$$

Since we desire to find the condition which exists when the weight supported by each wheel is a minimum, we will consider the values of F_1 and F_2 when R_1 and R_2 are minimum values.

We have previously shown that when D = O, R_1 is a minimum, and then the value of p is

$$\frac{2T_1 + 2T_2}{W_1 + 2W_2}g \text{ or } \frac{2T_1 + 2T_2}{W}g,$$

During an emergency application of the brakes F_1 and F_2 have a fixed value, and the values of T_1 and T_2 are obtained when R_1 is a minimum, from the following equations.

$$F_1 = T_1 + \frac{2.4w}{W}(T_1 + T_2); \quad F_2 = T_2 + \frac{2.4w}{W}(T_1 + T_2)$$

Solving for T_1 and T_2 we get,

$$T_1 = \frac{W + 2.4w}{W + 4.8w}F_1 - \frac{2.4w}{W + 4.8w}F_1. \tag{14}$$

$$T_2 = \frac{W + 2.4w}{W + 4.8w}F_2 - \frac{2.4w}{W + 4.8w}F_1. \tag{15}$$

Substituting these values for T_1 and T_2 in equation (8), bearing in mind that $R_1 = \frac{T_1}{f_1}$, equation (8) becomes

$$\frac{(W + 2.4w)F_1 - 2.4F_2}{f_1(W + 4.8w)} = \frac{W}{4} + \left\{\frac{W_1}{W}\left(\frac{h}{b} - \frac{k}{l}\right) + \frac{2W_2 d}{Wb}\right\}\frac{W(F_1 + F_2)}{W + 4.8w} \tag{16}$$

Now when R_2 is a minimum D is a maximum, and p = o. Therefore, under these conditions $F_1 = T_1$ and $F_2 = T_2$ obtained from equations (11) and (12). Substituting these values for T_1 and T_2 bearing in mind that $R_2 = \frac{T_2}{f_1}$ equation (9) becomes,

$$\frac{F_2}{f_1} = \frac{W}{4} - \left(\frac{h}{b} + \frac{z}{l}\right)(F_1 + F_2) \ldots . \tag{17}$$

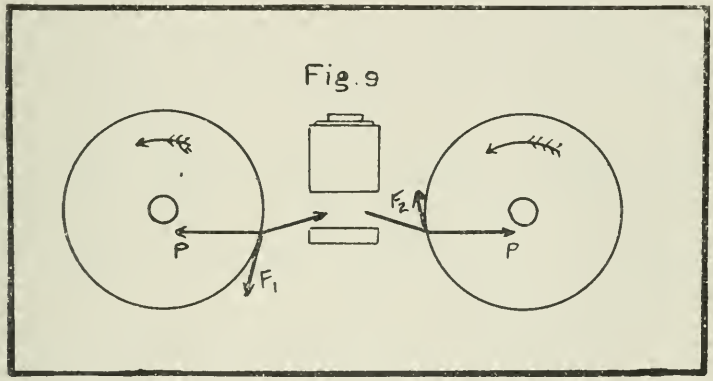
Combining equations (16) and (17) we get two equations from which we can obtain the values of F_1 and F_2, which will be the maximum brake shoe frictions upon the forward and rear pair of wheels, and may be used with perfect safety from wheel skidding in an emergency application of the brakes.

$$F_1 + F_2 = f_1\frac{W}{2} - \frac{\frac{l}{f_1}(W + 4.8w)}{W_1\left(\frac{l}{f_1} + \frac{k + z}{l}\right) + 2W_2\left(\frac{l}{f_1} + \frac{h - d}{b} + \frac{z}{l}\right) + 4.8w\left(\frac{l}{2f_1} + \frac{h}{b} + \frac{z}{l}\right)} \tag{18}$$

and

$$F_1 - F_2 = f_1 \frac{W}{2} - \frac{W_1\left(\frac{2h}{b} - \frac{k-z}{l}\right) + 2W_2\left(\frac{h+d}{b} + \frac{z}{l}\right) + 4.8w\left(\frac{l}{2f_1} + \frac{h}{b} + \frac{z}{l}\right)}{W_1\left(\frac{l}{f_1} + \frac{k+z}{l}\right) + 2W_2\left(\frac{l}{f_1} + \frac{h-d}{b} + \frac{z}{l}\right) + 4.8w\left(\frac{l}{2f_1} + \frac{h}{b} + \frac{z}{l}\right)} \quad (19)$$

So far we have determined that, first, the rear truck supports less weight than forward truck, and the rear pair of wheels less weight than the forward pair during an application of the brakes. This led us to the conclusion that if we design our riggings for the brake pressures, the front wheels of each truck must receive the greater pressures than the rear wheels.



The following discussion will show that this inequality of brake shoe pressures may be provided for by the proper inclination of the brake hangers.

Problem IV.

Fig. 9 represents diagrammatically the action of the brakes upon each pair of wheels of a truck, when the brake hangers are in line with the tangent to the wheel at the centre of the brake shoe. The same pull P is applied to each brake beam. The brake shoes exert on the forward pair of wheels a downward frictional force F_1, and on the rear pair an upward frictional force F_2. Now with whatever force the shoes act downward on the forward pair of wheels, the wheels will react with an equal and opposite force.

Similarly the rear pair of wheels will react with an equal and opposite force to F_2. Considering the forward pair of wheels, the upward force F_1 is directly resisted by the brake hangers, which are now under compression equal to the force F_1. Similarly the rear brake hanger is subjected to a tension equal to the frictional force F_2.

Consider now an exaggerated case, in which the angularity of the brake hangers is increased, as shown in Fig. 9. Each brake beam is subject to the same pull P. When the front brake shoes have been brought into contact with the forward pair of wheels, the force which is brought into existence by the friction of the two surfaces, tends to carry the shoe upward, along the surface of the wheel. But this action is resisted, by its brake hangers, on account of their excessive angularity. Thus there is a very strong tendency to force the forward pair of wheels away from the centre of the truck. This tendency of course is resisted by the truck frame and thus a powerful pressure is exerted on the brake shoes, in addition to that pull exerted by the brake beams upon the brake shoes. In this way the brake shoe friction F_1 is materially greater in this case than that in Fig. 8, where the angle of the hanger is such that it exerts no influence to force the brake shoes against the wheels.

The effect of this angularity of the brake hanger upon the rear pair of wheels is just the reverse to that upon the forward pair. The reacting downward friction of the rear pair of wheels upon the brake shoes tends to force the brake shoes away from the wheel. This tendency diminishes the frictional force which retards the velocity of the wheels. Now if the angularity is so increased that the brake hanger would be parallel or in line with the pull P then the frictional force practically becomes zero upon the rear pair of wheels, while the mere initial contact between the brake shoes and the forward pair of wheels would almost instantly result in creating such a high frictional force F_1 that the wheels would immediately be locked and skidded.

Therefore, we must conclude from this that between these two extreme cases or limiting values of the angle of angularity it is possible to so adjust your brake shoe hangers, that the increased and diminished weights supported by the front and rear

trucks will be taken care of by the increased pressure on the forward wheels, and the diminished pressure upon the rear ones. Thus we may proportion the frictional forces F_1 and F_2 in any way desired by a proper adjustment of the angularity of the brake shoe hanger.

It will also be observed that, if in Fig. 9 the wheels rotate in the opposite direction, what has been the rear pair of wheels will now become the forward pair. At the same time the effect of the inclined hangers upon the two pairs of wheels has been reversed, so that it is still, under the reversed conditions, the leading pair of wheels which is subjected to the greater brake shoe pressure, and the rear pair which is subjected to the reduced pressure.

Thus we are enabled by this method to design brakes to meet this transfer of weight from the rear to the forward pair of wheels.

The following description of the general action of railway brakes, and the nature of the frictional forces which are brought into existence, through an application of the brakes, is to some extent, a repetition of the discussion of Problem I. When a train is moving at a given velocity the adhesion of the wheels on the rails cause them to rotate. Every point on the surface of the tire moves around at the same rate as that at which the train is moving forward. But every such point, in relation to the forward movement of the train, comes successively to rest at the moment when it comes in contact with the rail. Now when the brakes are applied with a slight pressure only, the wheel continues to move round at the same rate as the train is moving, but with more difficulty. This increased difficulty in moving is shown, either in an increase in the traction force, which is required to keep up the forward movement, or, in cases where the accelerating force is not kept up, by the tendency of the moving mass to come to rest in a shorter time. But if the pressure with which the brakes are applied be increased, a point is reached, at which the friction between the brake shoes and the wheels first approaches, then equals and finally exceeds the adhesion of the wheel to the rail. This adhesion corresponds to the static friction which exists between two surfaces at rest. The point on the circumference

of the wheel, which is in mometary contact with the rail is at rest during that instant. Thus we apply the ordinary equations for static friction to obtain this adhesive force between the wheels and the rails. Now when the friction between the brake shoes and the wheels exceeds the static friction between the wheels and the rails, the wheels first begin to revolve more slowly, and finally cease to revolve at all and slide along the rails. In this case the static friction between the wheels and the rails changes to dynamical friction, or the friction caused by one surface moving over another. The coefficient of dynamical friction is much less than the coefficient of statical friction. This has been proved by experiment. And thus the retardation in this case is much less than that in the previous one. Therefore, the most efficient and the quickest stops are made, when the friction between the brake shoes and the wheels is a little less than the friction which can be obtained between the wheels and the rails.

The friction between the brake shoes and the wheels is a variable quantity, depending on the coefficient of friction between these moving surfaces. Captain Galton in a series of exhaustive tests and trials of railway brakes during the years 1878 and 1879, succeeded in obtaining the relation between the coefficient of friction and the velocity of the train. As the velocity of the train increases the coefficient of friction decreases. This is plainly indicated in the following table, constructed from Captain Galton's experiments.

V.	Coefficient of Friction f.		V.	Coefficient of Friction.		
	Calculated.	Observed.		Calculated.	Observed.	
0	.326	.330	45	.126	.127	...
5	.277	.273	50	.118	.116	....
10	.241	.242	55	.111	.111	....
15	.213	.223	60	.105	.074	....
20	.191	.192	65	.099	....	....
25	.173	.166	70	.094	....	....
30	.158	.164	80	.085	....	....
35	.146	.142	90	.078	....	....
40	.135	.140	100	.072	....	....

These values of f can only be used, when the conditions are the same as those under which these trials were conducted, that is with cast iron shoes and steel tired wheels.

Captain Galton from a further study of his experiments, found that the point at which the rotation of the wheels is arrested, so that they slide on the rails, depends upon the amount of friction between the brake shoe and the wheel, the weight upon the wheel, and the condition of the rails which govern the adhesion between the wheels and the rails. Therefore, with the same weight upon the wheels, and the rails in a similar condition, the same amount of friction will stop the rotation of the wheels, no matter at what speed they are revolving. The relation then that the speed has to this subject is, as stated before, that as the speed increases the brake shoe pressure must also be increased to make up for the decrease in the value of the coefficient of friction and still maintain the fricton constant or a maximum.

Another feature that was brought out by these experiments, was that as the duration of time of the application of the brakes increased, the friction between the brake shoes and the wheels decreased. This the above experimenter explains as follows:— "Each surface is composed of a series of small mountains and hills and the longer the surfaces remain in contact, the quicker are these irregularities worn down, and thus the friction between these surfaces will at the same time decrease." The following table illustrates the point fully:

Dynamic Friction Cast Iron or Steel.	Velocity.		Coefficient of Friction.				
	Ft. per. Sec.	Miles per hour	At Commencement.	After 5 Secs.	After 10 Secs.	After 15 Secs.	After 20 Secs.
Just coming to rest.....	1 to 3	$\frac{3}{5}$ to 2	.250				
When moving at.....	10	6.8	.242				
" "	20	13.6	.213	.193			
" "	25	17.0	.205	.157		.110	
" "	30	20.4	.182	.152	.133	.116	.099
" "	40	27.3	.171	.130	.119	.081	.072
" "	45	30.7	.163	.107	.099		
" "	55	37.5	.152	.096	083	.069	
" "	60	40.9	.144	.093	.070		
" "	70	47.7	.132	.080	.070		
" "	88	60.0	.072	.063	058		

It is evident from consideration of Table I, that the pressure, which if applied would stop the rotation of the wheels when the

velocity is great, is much larger than that required to stop them when their velocity is small. Thus we may apply to the brake shoes at the beginning of the application of the brakes when the speed is high, an excessive pressure; and as the speed slackens gradually reduce this pressure. so that there will be no liability of the wheels ceasing to revolve before the train is brought to rest.

The force which may be exerted on the brake shoes besides being dependent on the speed of the train, is also dependent on the condition of the rail. The condition of the rail affects the coefficient of adhesion between the rail and the wheel. And since the frictional force caused by the brake shoes must not exceed the friction between the wheel and the rail, the brake shoe pressure, which may be used is dependent upon the coefficient of adhesion. The following table gives approx results showing the proportion that the brake pressure should bear to the weight on the wheels at different speeds and with different coefficients of adhesion for the rail and wheel contact.

Speed.		Approximate Ratio.			
Feet per hour	Miles per hour	Coef. of adhes. .30	Coef. of adhes. .25	Coef. of adhes. .20	Coef. of adhes. .15
11	7.5	1.2	1.04	0.83	0.60
22	15.0	1.41	1.18	0.94	0.70
29	20.0	1.64	1.37	1.09	0.82
44	34.0	1.83	1.53	1.22	0.92
59	40.0	2.07	1.73	1.38	1.04
73	50.0	2.48	2.07	1.65	1.24
88	60.0	4.14	3.47	2.77	2.08

The coefficient of adhesion is affected by the condition of the rails. In wet weather and with a greasy rail the coefficient is small. With a dry rail the coefficient is high. If sand is applied under each wheel when the rail is in its worst condition, the coefficient is increased to near the value it has when the rail is dry.

For passenger service 90% of the weight of the car, when empty, is the maximum brake force allowable. And for freight service 70% of the weight of the car when empty, is the maximum allowable brake force.

SIGNALING.

By R. Latham.

There is perhaps no other branch of railroad engineering that has taken such great strides within the last thirty years as signaling. Its growth has necessarily accompanied the vast increase of traffic, higher speed of trains and the multiplication of grade crossings, both highway and railroad, the latter of course being the most important. We have to look to some of those splendid systems in the United States to find perhaps the most perfect systems of signaling. The mileage of railroads on this continent is necessarily very great, hence the great expense of complete signal equipment; yet the demands of traffic have warranted in some cases, the installation of the most modern and expensive apparatus to protect the trains while running at lightning speed, and to keep them so spaced that there shall be ample distance in which they may be brought under full control and if necessary to a dead stop, in case of derailments or accidents ahead, and so avoid collision. Protected in this way we have trains running sometimes within sight of each other at speed greater than a mile a minute without the slightest danger of collision (provided the trainmen are in their proper senses), all signals being visible day and night.

The problem of grade crossings have been greatly simplified without elevation or depression of tracks. This is of great importance, especially in America where there are so many even on important roads. The clumsy and costly precaution of stopping a train at every grade crossing is now done away with by the aid of interlocking apparatus and signals, with the greatest safety and success.

The first expense of installing these interlocking plants is, of course, high, involving as they do a system of signals and derailing apparatus with the necessary mechanical connection with an interlocking tower, and there is the secondary and constant expense

of manual operation. But it has been found that even with the lightest traffic on single or double tracked roads that the sum saved annually pays a high rate of interest upon the investment.

A great deal could be written on the subject of signaling. It is not in its highest stage of development and so far its fundamental principles are not by any means numerous. Experience has taught that to space trains by time is vastly inferior to spacing them by distance, but it is a strange fact that only about fourteen per cent. of the railroads in America use the latter system, the rest using the former or some modification of it. The idea of the "space interval" system originated in England where the "time interval" system also was in use, and it was only a short time after the first trains were run under the space interval or block system that practically every English road had adopted the same system. In America the "time interval" system, which is practically a flagging system when trains become disabled, was in use as in England, but unlike the English, the "train despatcher" system was introduced as an intermediate step between the "time interval" and block systems, two systems which vary so much in their principles. It is a fact worthy of note, that wherever the block system has been introduced, it has never been abandoned, so satisfactory have been its results.

In this paper, no attempt will be made to exhaust the subject, but a sketch of English and American practice will be drawn, paying more attention to the latter, as it seems to show signs of higher development than the former, although the English still hold the record for the least number of accidents due to false signals. The fact that the English ideas of signaling are far more conservative than American, perhaps accounts for the fact that there are practically no automatic block signals in England, while in America they are becoming numerous, owing to their economy and satisfactory results. It is the intention of the writer to compare briefly the English and American practice after the principles of each have been described, so that the relative advantages and defects of each may be noted; the reader of course being at liberty to judge for himself from remarks made, which seems to him the better practice of the two.

Manual Block Signaling.

Manual block signaling is the system universally employed by English double tracked roads. The system was introduced about 1853, and subsequently parliament passed an act requiring its adoption by all important passenger lines. The consideration of such a system means a study of English practice, with its forms of signals, colors, and rules of operation.

The term "block signaling" is applied to that arrangement of outdoor signals and electric communication by which two trains may be kept spaced. In other words, the line is divided into sections or blocks whose lengths vary with the necessities of traffic. Lines with heavy traffic or great frequency of trains, have blocks a mile in length and sometimes less; those which run trains less frequently, have sections as long as five miles. Only one train is permitted to be in a block at a time and permission to enter a succeeding block is given by an attendant situated in a signal tower at the beginning of that block. The attendant at each block cabin keeps watch of the trains passing him, records the time of their arrival and informs the attendant at either side of him. He sends to the signal tower in advance a warning that a train is approaching and to the tower in the rear the assurance that same train has arrived and passed his cabin, thus authorizing the latter to set his signals for a second train.

The English block system has remained practically unchanged for the last quarter of a century. The invention of new mechanical "locking" devices has wrought some slight changes, but the methods have remained the same. A series of signal cabins or towers placed at different distances (according to the length of the block), keep the trains so spaced that only one train can be in a block at once (except when "permissive" blocking is done). These cabins are so located that they can operate switches and cross-overs from main lines. Near important towns and junctions they are often placed within sight of each other, as the distance from switches must not exceed about 540 feet in the case of split switches, and 900 feet in the case of throw switches, in order that they may be workable. When once a train has been despatched from a town its running is left entirely to the cabin operators, so that

safe handling depends entirely upon the watchfulness and obedience to rules on the part of the operators themselves. The operation of one signalman is contingent upon that of another owing to the use of electric locking apparatus between two succeeding cabins, and by having electrical communication, both may act in conjunction.

When operator at A wishes to send a train into the block section A-B by push button and bell signal, he registers "be ready" on an indicator instrument with which each cabin is supplied, and then it is repeated back to A, whereupon the operator at A gives a description of train by bell signal, and if B is ready to accept train, he puts the handle of his instrument in the position meaning that he accepts train. This causes indicator at A to go to "line clear," whereupon A can set his signals at "safety," after which he gives a dial signal to B, showing train on line, which B acknowledges. Such messages require only a few seconds for transmission, so that the fastest flyer may proceed from block to block finding signals set at "safety" for each block, although normally at danger. When the blocks are short and trains frequent it will sometimes keep the signalmen on the alert, to have their signals properly set, and in this case the operators are permitted to give the warning "be ready" in advance, so that the signals may be "pulled off" considerably in advance of passing trains.

Sometimes more than one train is permitted into a block at one time. This is called "permissive" blocking, and is only practiced on busy freight tracks, on block sections in large cities. The operator A records the number of trains he has allowed into the block, and operator B recording when each train leaves the block, keeps operator A posted as to how many trains are left in the block.

Form of Signals.

Practically the only form of signal in use on the important lines of England, are of the semaphore type. For main line switches a ground disc signal is used. The almost exclusive use of the semaphore type is the result of a joint agreement of the roads. The Board of Trade, which has power from parliament

to control in some respects the railroads of Great Britain, has recommended the universal employment of the semaphore type and it has therefore become the standard signal for practically all lines.

The English semaphore differs little from others; the blade or arm is about 6 feet long and 9 inches wide throughout there being no taper to the arm, unlike the American. The blades of home signals have square ends, those of distant signals have fish-tail ends. Those for low speed or freight tracks are distinguished from those for high speed tracks by a white circular ring on the face and a black one on the back. The horizontal position of the arm is taken to mean "danger" or "stop," while the inclined position (at 45° or 60° with the horizon) "safety" or "proceed." When there is nothing on line these are set at danger or in the horizontal position, or, in other words, the "normal" position of the semaphore is always at "danger." This seems to be a rule of English railroad signaling that is observed on every road. The block signals are interlocked with main line switches nearby, the signal cabins being so placed as to serve the purpose of interlocking towers for the switches.

Color of Signals.

The blades of the home and distant signals are painted alike, red on face with a white band across it, and white on back with a black band across it. Nearly all important roads have adopted green for safety and red for danger for night signals. Originally, white was the standard color for safety, which is still the case on the majority of roads in America. To change from one color to another means a great expense to a railroad, so it would have to be almost a case of compulsion before such a step would be taken. The fact that in such a densely populated country as England an observer at night would see nothing else but white lights is the reason for such a change. It was found that a distinctive color for safety was required so that the engineer would not mistake the light on some bridge, or in a house, for his safety signal. This is perhaps the strongest objection raised to the use of white light for safety, and it has had such weight with managements of the various roads, that in spite of the great expense in-

volved, they have one and all abandoned the white and adopted the green light for safety.

A second reason for the change from white to green, lies in the fact, that it was the custom of some roads to have their semaphores show a green light (meaning caution) in large stations and busy yards, as the running of trains through these parts had to be done with the greatest caution. The arm would be set at "safety" while the light indicated "caution." In the country the arm would be set at safety while the light indicated "proceed." This inconsistency led to the belief that a signal meaning caution should be discarded as unsafe, and that there should be but two signals, "stop" and "proceed," and if caution in running through certain districts be required, let it be expressed by order board or written order.

Placing of Signals.

The position of signals, so that they may be viewed with ease, is a problem not always easy to solve. The shape of the road, the presence of cuts or bluffs, will present difficulties in placing signals. In England, railroads run exclusively on the left hand tracks, and this practice is carried on to some extent in America. In most cases the signal posts are placed to the left of the track they govern, the arm pointing away from it. This is the rule, but it often happens on curves that the signal post governing the left hand track is placed on the right of the railway line, making the situation rather complicated to the observer, but to the engine driver who knows every foot of his road, perhaps this is of little consequence. He of course can remember the rule that all signals governing his train have the blades pointing to the left from the post. This rule,of course, is of use to him only during the day when the blades are visible, but at night he has to be on his guard and know the peculiarities in the placing of signals.

Sighting of Signals.

The "sighting" of signals, *i.e.*, the placing high or low that they are visible to the engine driver, is done with the greatest care so as to get the best possible height for clear vision. Posts as high as

fifty feet are required for this purpose, and even then it is sometimes necessary to build a back ground for signals in order to make them visible day and night. On four track lines and near junctions and terminals, where there are numerous parallel tracks, signal bridges spanning the tracks are constructed high enough to give ample head room for brakesmen. These structures are built light, usually of iron, and afford the best means of placing signals as each track can have its governing signal directly over it. Instead of these bridges a cheaper stand for signals is found in bracketed posts, a signal being placed on each bracket. This means of placing signals is getting away from the simple and natural way of having each signal directly over the track it is intended to govern, and then there can be no mistake in the interpretation of the signals.

Distant and Home Signals.

In English block signaling there is really no difference between the home and distant signal as far as the position of the blades and color of lights are concerned. The distant signal has the fish-tail end while the home has the square end. At night, however, only the lights are supposed to be seen, and red and green are used for "danger" and "safety" on both home and distant signals. If an engine driver finds his distant signal at danger he knows that he may expect to find the home at the same, and slackens speed so that, if necessary, he may come to a full stop without passing the home signal. The distant signal then is simply a forewarning to the engine driver as to how he may expect to find the home signal.

The home signals mark the end or the beginning of the block and are therefore placed opposite the signal towers. The distant signals are placed from 2,000 to 2,500 feet in the rear of the home signals, giving sufficient distance for the speediest and heaviest trains to stop before passing the home signal. When permissive blocking is done the train is required to come to a full stop at the home signal and is then allowed to proceed on verbal order from the towerman. When the blocks are short (about $\frac{1}{2}$ mile) the distant signal of a block is often placed on the home

signal post of the block in its rear. This is found convenient and economical. The fact that a distant signal might not be visible owing to the lamp being out or burning dimly is provided for by means of an apparatus which rings a bell in the cabin. In foggy weather, torpedoes are placed on the track opposite the distant signals as a warning to the engine driver that he is approaching the home signal.

American Block Signaling.

The manual blocking just described is practically the only system of signaling in use on English railroads, and it has been found to be the only practicable one suited to English traffic which necessarily is very heavy. In America different conditions prevail. The railroads here have a great mileage, many lines have only one track, some two, three and four tracks. Some of these run through country sparsely populated as well as through thickly populated districts, so that we often find more than one system of signaling on the same road, the system being more complete in the thickly populated districts than in the open country.

Telegraph Blocking.

The simplest form of block signaling in America is the telegraph block system. This resembles very much the English manual blocking, but has not the same degree of interlocking of switches and signals as the latter. It is used only on lines of great traffic between important cities where trains run very frequently. It is fast being superseded by the automatic system as the expense of operating involved in salaries of operators, maintenance of apparatus and structures is great compared to the latter.

The track is divided into blocks or sections varying in length from one to four miles. Signal cabins are placed at the beginning of each block. The signals operated from these cabins authorize trains to enter the various blocks. Figure 1 represents a block section with the home signals a & b. A train in passing in the direction A B is permitted to enter the block by the lowering of semaphore arm of signal a, operated by the attendant at cabin A. If arm of signal a is in the horizontal position, the engine driver knows that block is not clear and awaits until it

is lowered, when he may proceed as far as signal b, where he gets permission to enter the next block B-C. After train has passed cabin A, it is the duty of the attendant at A to bring his signals to danger—the normal position of all home signals. After train has passed B, he notifies A, so that he (A) may lower his signals for another train.

Signals.

The signals are of the semaphore type, with the arm so arranged as to give three positions. The arms are from five to six feet in length and taper towards the point of suspension. The home signals are painted yellow or red on the face with a band near the end, and white on the back. The distant are painted green on the face with white on the back. They are mounted

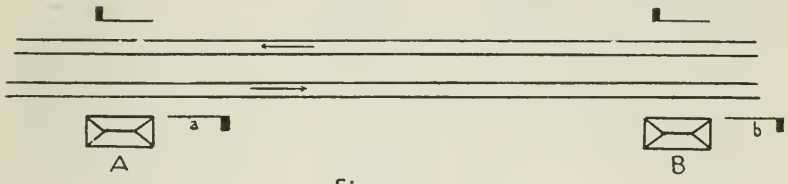


Fig. 1

on wooden posts usually from 20 to 30 feet high, set on the right hand of the track they govern with the blade swinging to the right of the post. A counterweight causes blade to assume the horizontal position should the wire connection between the cabin and the signal post break. Distant signals are used as an indication of the position of the home signals, being fitted with white and green lights, the home signals showing three lights—red, green, and white. They are placed from 800 to 2,500 feet from the home signals, the levers operating each are interlocked so that distant signals cannot be thrown to safety until the home has assumed the same position; and therefore a home signal can be thrown to the danger position the distant must be thrown to "caution." Where blocks are short it is found economical to place the distant signal of a block on the home signal post of the block in the rear.

Figure 2 is a sketch of the three position semaphore; the semaphore casting is so constructed as to carry red and green lenses. The position (a) means danger, (b) caution, (c) proceed. Positions (b) and (c) are the only ones assumed by the distant signal. Where blocks are long, it is often desired to do "permissive blocking," or allow more than one train in a block at once. The home signal is made to assume the position as shown in (b), which means that the train may proceed with caution, or else the signalman may leave his home signal at danger, and use a green flag (by day) or light (by night) to allow a second train into the block.

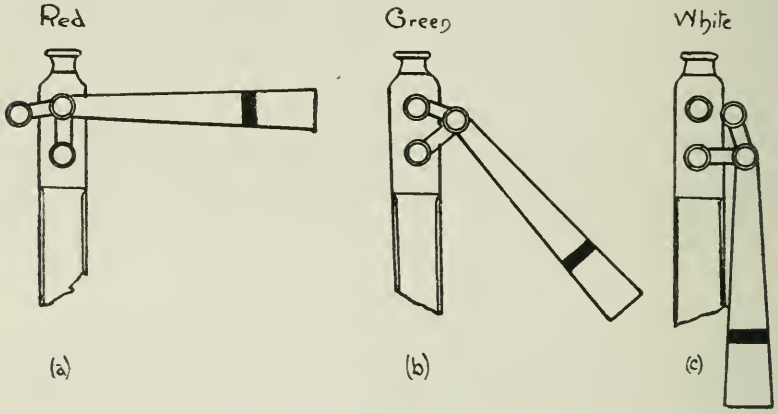


Fig 2

Single Track Blocking.

Not only has the simple telegraph block system been in use on lines of two tracks or more, but also on lines of single track. The success with which such a system has met seems to have led largely to its adoption on single track roads. A system of signaling that will give full protection to trains as well as quick handling on lines of two, three or four tracks will give the same results on single track lines. This system has proved a success even when stations are twenty miles apart, provided there is not too great a frequency of trains. With trains running every hour

and stations not exceeding thirty miles apart, this system has been used advantageously, the station agents under the direction of the train despatcher, performing the duties of signalmen. The train despatcher arranges the spacing and crossing of trains. Orders are received by the station agents who must operate their signals accordingly. A train having reached a certain station, has semaphore set at "clear," so that it may proceed. This does not indicate that the block ahead is clear, but merely that so far as is known by the agent at that station, it may proceed. But the engineman having received duplicate orders from the train despatcher can proceed to the next station or side track where they meet and cross an opposite train to which similar orders have been given.

The signalman at each block station is required to keep his block signals set normally at "danger," except during hours when his particular signals are authorized to be closed. The closing of signals is only done when there is a scarcity of trains. Blocks are thus made larger, so that through freights and passenger trains may be allowed to pass stations without slackening speed.

Forms of Signals.

There are different forms of signals in use in single track blocking, some roads having designed special semaphores. Those described in the double track blocking are the commonest. Three phase semaphores with the horizontal and two inclined positions of the arm, one being above the horizontal are in use. The latter position is used when it is desired to do permissive blocking (only done of course with trains running in the same direction). The latter then is a cautionary signal and means proceed with caution. The arm is inclined at 60° to the horizontal in both the caution and clear positions.

Position of Signals.

Each set of signals (home and distant) is placed to the right of the track so trains will always find governing signals to the right. The arms are swung to the right. Distant signals are placed from 800 to 2,500 feet from home, according as the grades and curves run in the vicinity of the block station. The home

signals are often placed on the block station itself, having only one home for both directions and operated from inside. The distant signals are operated solely by hand power, having pipe and wire connections from a lever to the signal post.

The Controlled Manual Blocking.

The controlled manual blocking used in American practice, is almost identical with English manual blocking. It is so called because the operations of a signalman at one end of a block are contingent upon those of the signalman at the other end. This is made possible by the use of electrical apparatus invented by "Sykes," an English engineer. Briefly, the apparatus consists of a series of electro magnets so connected with the levers operating the signals at one end of the block (call it A), that the levers operating signals at the other end of the block (call it B) control those at A. In order that a train may be admitted into a block A-B, the permission of both A and B is required. For example, when A sends a train to B he at once places his signal at danger, and it is impossible for him (A) to release that signal until B unlocks it, and B cannot do that until train has cleared the section. In case B should, by mistake, try to unlock A's lever before train had cleared the section, an automatic arrangement is provided so that A after having admitted train and placed his signal at stop, cannot unlock his signal to "clear" until train itself has actually passed out of the section. This is done by running an electric circuit controlling A's lever, through two or three rail lengths of track just beyond B. The current goes from the battery to one rail of the insulated section of track, thence by wire to A's signal, which it holds "locked" at "stop" by energizing an electro-magnet. When train passes over the insulated rails most of the current passes through the wheels and axles from one rail to the other, and thence back to the battery without going to the electro-magnet at A. This demagnetizes that instrument so that signal may be cleared for next train.

The automatic arrangement becomes useless if permissive blocking is done. There being two trains in the section, the first

one will release A's lever while there is a second train in the section, thus allowing a careless operator to clear his signals for a third train.

The form and color of signals are similar to those used in telegraph blocking.

A full technical description of the controlled manual apparatus may be found in the Railroad Gazette of August 24, 1900.

Automatic Block Signaling.

The manual system of block signaling is the most expensive of all, owing to the cost of operating. In America where the mileage of railroads far exceeds that of English, it is not surprising to find it adopted by comparatively few of the roads that favor the block system. It is only in use over small sections of line running through a populated country between important towns. The manual system here referred to is that where the blocks are made short, and stations for sole object of signaling are built at the beginning of each block. The employment of an attendant night and day at every station is an expense which few American roads could bear, and the first expense in establishing these stations for the sole purpose of signaling would sink many roads into ruin. Even the lines that have adopted the manual system, owing to the enormous expense have been deterred from placing the block signals as near together as they ought to be for convenient working. In consequence of the excessive lengths of the blocks they have introduced the permissive system, virtually suspending for the time the safeguards of the block system. This seems to be equivalent to throwing away a portion of the money spent for the erection and maintenance of plant.

As the result of the enormous expense attached to the manual operation of block signals, various automatic devices have been invented to eliminate the employment of human attendants. These depend upon the aid of electricity and compressed air, although elaborated systems have been devised from which electricity was eliminated altogether. American signaling authorities claim that automatic devices to replace the manual operation of signals, afford the most perfect and economical means of spacing and handling trains. The automatic system is the outcome

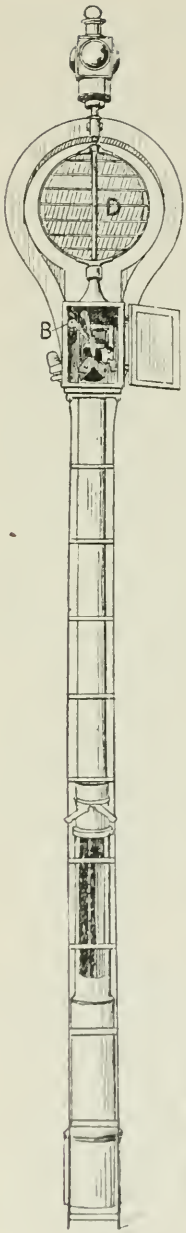


Fig. 3.

of necessity arising from a great mileage with increasing traffic, with a financial inability to employ human attendants.

The earlier forms of automatic signals depended, for communication between blocks, upon wires strung on poles. Electrical apparatus was used to hold a signal at the beginning of a block at "danger" until train had cleared that block. Owing to fact that a train might break in two, leaving one portion of it in a section while the other had cleared, the track circuit system was adopted.

Track Circuit System.

In this system the current is conducted by the rails of the track and so long as that current remains uninterrupted the signal is held at safety by an electro-magnet. A train entering the section makes a metallic connection between right and left rails. The current being interrupted causes signal to change from safety to danger.

Signals.

Figure 3 represents a form of disc signal used commonly in automatic signaling. It is mounted upon a hollow iron post about sixteen feet high. It consists of a disc or target D, which is fixed to a vertical spindle on the top of which the lantern stands. The latter has red and white (or green if white is not used for safety) lenses on opposite sides. The spindle is connected with clockwork (in box B) operated by a weight which hangs down the centre of the post. The weight has to be wound up at regular intervals.

The disc D is painted red on both sides, and when set with its face towards the engineman means "stop," when turned with its edge towards the train means all clear. Sometimes a second disc fixed to the spindle and at right angles to the red disc is used. This is painted white (or green if white is not used) on both sides and indicates "all clear."

The clockwork is governed by an electro-magnet. As the current ceases the clockwork is allowed to move until the spindle has been turned through a quarter of a revolution. In case the clockwork should be run down completely and by chance leave the signal at "all clear," the current is made to pass through a pair of springs which are held together when the weight is wound up, but which are separated when the weight has nearly reached the bottom; so that just before the clockwork is run completely down the current is opened and signal left standing at "stop."

Positions of Signals.

Home signals are usually placed directly at the beginning of the block they protect, and to the right of the track they govern if it is the rule for trains to run on the right hand track. In order that the enginemen may know that signals are working properly, a block signal standing at "all clear" is made to change to "danger" when the train is within 200 feet of the block. The objection sometimes raised to this, is that a misplaced switch might cause the signal to move to danger just as the train was entering the section, and the engineer would naturally suppose that his train was the cause of it. On the other hand, where signal changes to "danger" after train has entered section, there is no check upon the working of the signals. To station brakemen, on the rear end of trains, to observe the working of signals is attended with too much difficulty to be practicable. But in any case where automatic signals are used, there should be no doubt as to their efficiency, as experience has proven that care and close inspection of apparatus warrant the assumption that dangerous failures—the greatest of which is failure to go to "stop" when train enters a section—will not occur.

Arrangements of Signals.

Figure 4 represents an arrangement of automatic disc signals. In this system the signal stands "normally" at danger until a train enters the block in the rear, and then if everything is clear in the block, it assumes the clear position, which it retains until the first pair of wheels passes the block insulation shown -[]- when it assumes the "danger" position. Train A having passed D, H, and D_2 holds them at danger, but since the clearing section of H_2 has been entered the signal H_2 stands at safety.

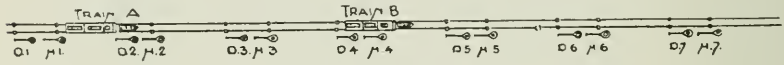


Fig. 4

Train B has entered the clearing section of D_5 and H_5, but a broken rail shown -( )- in advance holds them at danger, for which reason train B will stop upon reaching H_5 and then proceed with care until it reaches D_6 and H_6, which are in the clear position. D_7 and H_7 naturally stand at danger, since no train has entered the clearing section in their rear.

Overlaps.

Instead of providing distant signals the overlap is employed. By an overlap is meant one block section overlapping another. The overlap is about 2,000 feet long and is only used when the "normal danger" arrangement of signals is employed.

Fig. 5

Figure 5 represents an arrangement of signals where there are no distant signals, the overlap being used instead. A signal occupies the danger position until a train enters the block in its rear, and then if everything is safe on the block and overlap in advance it assumes the clear position, which it retains until the first pair of wheels passes the block insulation shown -[]- near the foot of the signal post, when it resumes the danger position

and holds it under all circumstances until the last pair of wheels has passed the overlap insulation, shown -||- beyond the next signal in advance. The signal may then be cleared by an approaching train as in the first instance, but will otherwise remain at danger. Train A having passed S_1 holds it at danger, but as it has entered the clearing section of S_2 and nothing intervenes in advance, S_2 is found in the clear position. Train B having passed into the block of S_4 holds it as well as S_3 whose block it has not entirely left, at danger. Under ordinary circumstances S_5 should be in the clear position, since there is no train in advance of it, but in this case there is a broken rail, shown -( )- which holds S_5 at danger. For the same reason S_6 is in the clear position, for in this arrangement of circuits, it is the interruption of the circuit in the block immediately in the rear of the signal which tends to clear that signal. This feature, which at first glance seems singular, is consistent, since it is the danger in *advance* of a signal which it is supposed to indicate. Train B will pause upon reaching S_5 and after waiting a certain number of minutes will proceed with care through the block section until it reaches S_6, when its course will be clear.

Wire Circuit System of Automatic Block Signals.

Those who favor the wire circuit system claim that the track circuit is not so scientific as the former, and that a broken rail, although serious enough to cause derailment, does not affect circuit sufficiently to cause a danger signal. The wire circuit system operating *enclosed* disc signals is perhaps the most efficient and reliable, owing to the simplicity of its apparatus and to the fact that the current is conducted by wire.

Form of Signals.

Figure 6 is a cut of the signal itself. It consists of a hollow case of metal or wood with a white glass aperture, and painted black, which forms a contrasting color to white (safety) or red (danger), thus forcibly attracting the attention of the engineer. Figure 7 represents the interior of the case. It contains an electromagnet which, on being energized, holds a red disc (made of silk

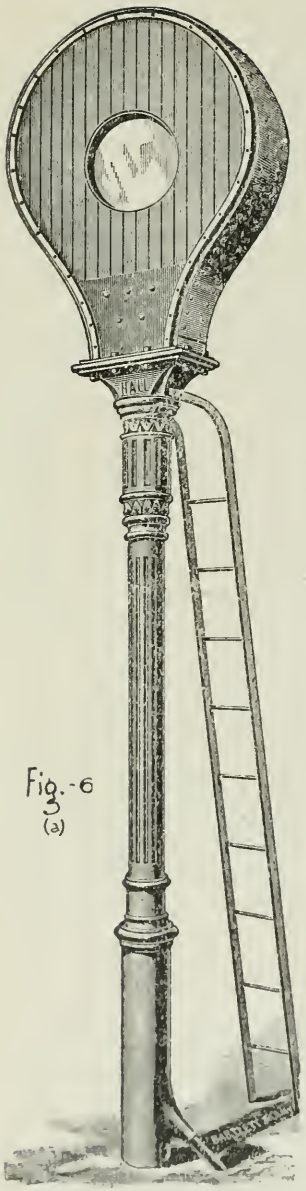


Fig. 6 (a)

"LINE CLEAR"

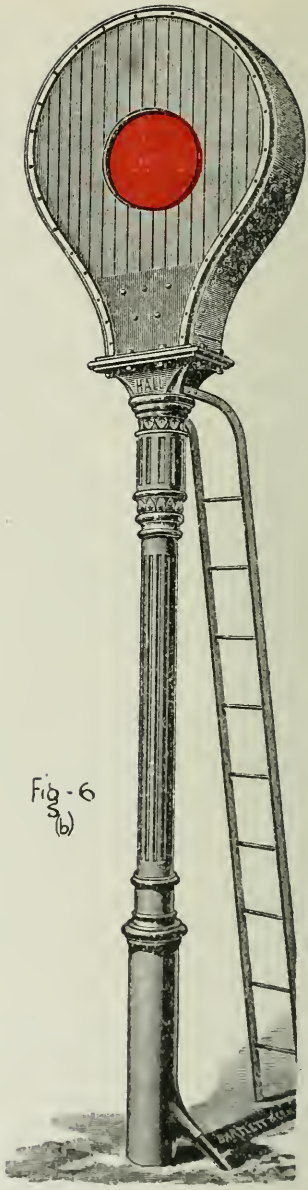
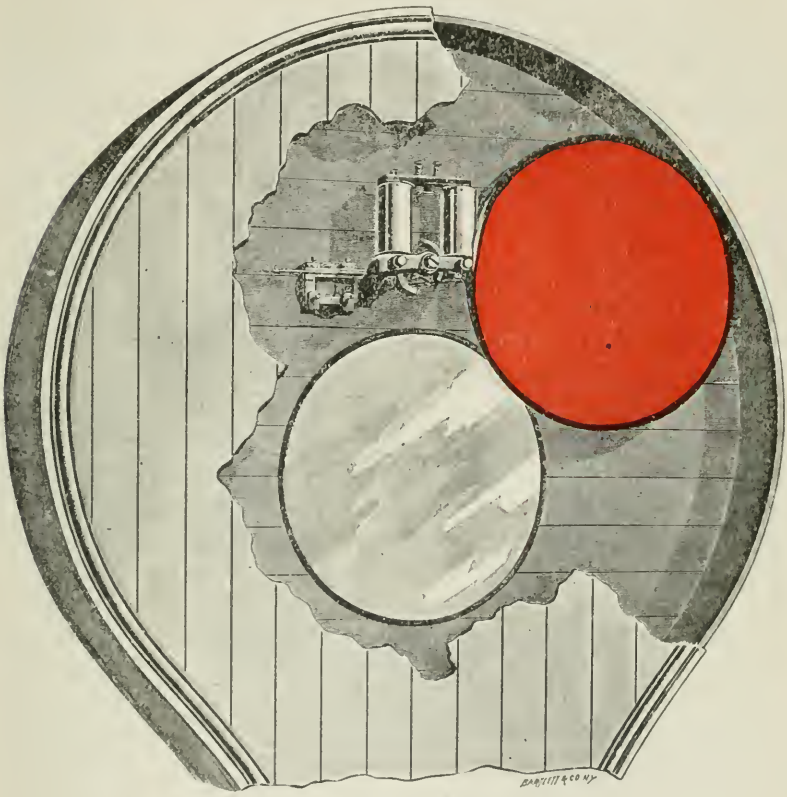


Fig. 6 (b)

LINE BLOCKED"

stretched on an aluminum ring) up, which otherwise would fall down owing to gravity and cover the glass aperture making the danger signal. A white reflector is shown through the aperture when the red disc is drawn up, making the safety signal. The position of the lamp is shown in Fig. 6. During the day it is hung below the glass.



INTERIOR VIEW OF SIGNAL CASE

"SAFETY."

POSITION OF SIGNAL (BY ELECTRO-MAGNETISM)

Fig. 7

Distant Signals.

The distant signals are practically the same as the home, only the discs are green instead of red. They are included in the cir-

cuit, and therefore act in conjunction with the home; that is, a green distant signal indicates that the home will, or is likely to be, red. A white distant signal corresponds to a white home signal. They are placed about 1,000 feet in advance of the home signal. By a judicious arrangement of these distant or cautionary signals, no home signal need ever be made visible beyond a few hundred feet.

The prominent feature of the enclosed disc signal is that the moving parts are protected from wind and rain and snow, and therefore can be made light enough to be moved by an electro magnet of moderate size.

The principle upon which this signal is operated and constructed is that the first wheel entering a block section sets the signal at danger, and at the same time breaks an electric circuit in such a way that under no possible contingency can the signal again show safety until the train passes out of the block section and operates a track instrument which restores the circuit. If a wire breaks or is grounded, or two wires become crossed, the signal falls to danger by gravity. The failure of the battery or derangement of parts always brings signal to danger. In other words the safety position of the signal is dependent upon an uninterrupted circuit through the magnets of the signal instrument in the case. It is simply the attractive power of electro magnetism that holds the signal at safety. The movement of signal to danger position is not dependent upon the action of force such as the unfastening of a mechanical lock or opening of a valve, but simply by the action of gravity on the interruption of the electric current from a lack of force to hold it in the safety position. The safety position therefore is only assumed when all the apparatus is in perfect order and no train has entered the section.

Track Instruments.

Track instruments are used to break and make the circuit, being operated by the wheels of passing trains. Two are required for each (simple) block. The first, called the "block" instrument, is located at the beginning of the section, and is constructed as to break the circuit (when operated by train) so that the home and distant signals fall to danger and caution respectively. The

second, called the "clear" instrument, is placed about 2,000 feet beyond the beginning of the succeeding section, so that when the first pair of wheels of the longest train has operated that instrument (thus closing the circuit), the whole of the train will be out of the first section.

"Clear" Track Instrument.

Figure 8 represents sectional view of the clear track instrument for closing the circuit. L is a lever or treadle operated by a passing train. The lever being depressed at track end, forces

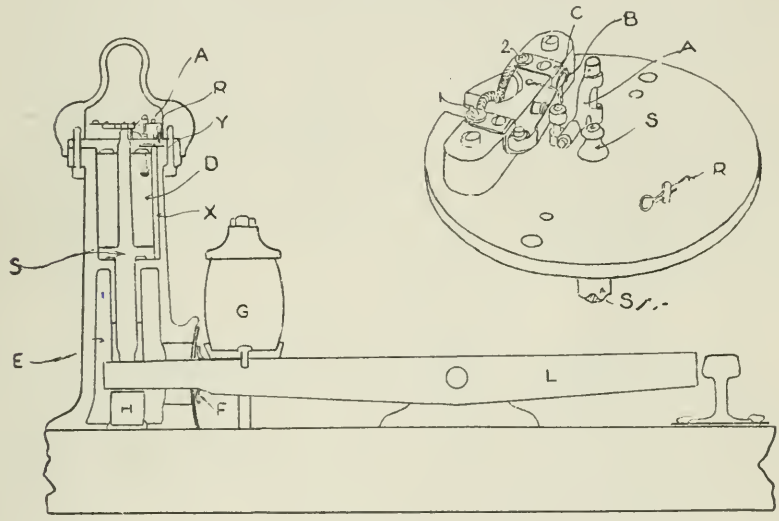


Fig. 8

the piston S moving in an air chamber D, and communicates motion to the key lever A of the circuit closing apparatus. The upper and lower ends of the air chamber are connected by a post X, so arranged that when the piston is forced upwards a portion of the air above the piston is forced out through the opening Y. When the piston has risen high enough to cover the opening Y, communication with the lower end of the cylinder is cut off and the air remaining in the upper chamber forms a cushion, preventing the piston from being thrown forcibly

against the top cap. Upon being actuated by the lever L its bevel top engages a roller on the arm A, which forces the spring B to a contact with its anvil C, thus completing a circuit between the wire connections of 1 and 2.

The piston having been raised by a passing train the air above it is driven through the port X and enters the air chamber below the piston, thus forming a cushion preventing serious shocks. R is a valve for regulating air pressure, The lower end of piston rod moves in closed chamber E. Movable plates F attached to the levers keep this opening closed. H and G are two compresser rubber springs, so that hand cars, velocipedes or any weight less than an ordinary car wheel will not operate the piston.

The track instrument just described is used to close the circuit, being so placed as to allow the longest train to have cleared a section before the signal protecting that section assumes the clear position. The "block" instrument is alike in principle and construction to the "clear" track instrument, except that in the case of the former, the current is broken when lever is actuated by the wheels of a passing train.

Block Signal Circuits.

Figure 9 shows the arrangement of battery wires and instruments for operating a simple circuit. D is block instrument (heretofore described), placed at the beginning of the block section. B is the clear track instrument situated at the other end of circuit, or about 2,000 feet beyond the beginning of the next block. R is a relay and X the battery, both of which are located anywhere within the block. In Fig. 9 (^{a}) the circuit is closed and signal is held at safety, the circuit being from battery X wire 1, anvil E, spring D, wire 2, electro-magnet S, wire 3, contact points p, p^1 of relay R, wire 4, electro-magnet r, wire 5, to battery. The first wheel of a train entering a section operates the block track instrument breaking the circuit between spring D and anvil E, demagnetizing electro-magnets r and s. Signal falls to danger and contact points p and p^1 are broken. When train has completely cleared the block track instrument D, contact between spring D and anvil E is restored, but as circuit is still broken at points p, p^1, the signal will remain at danger until

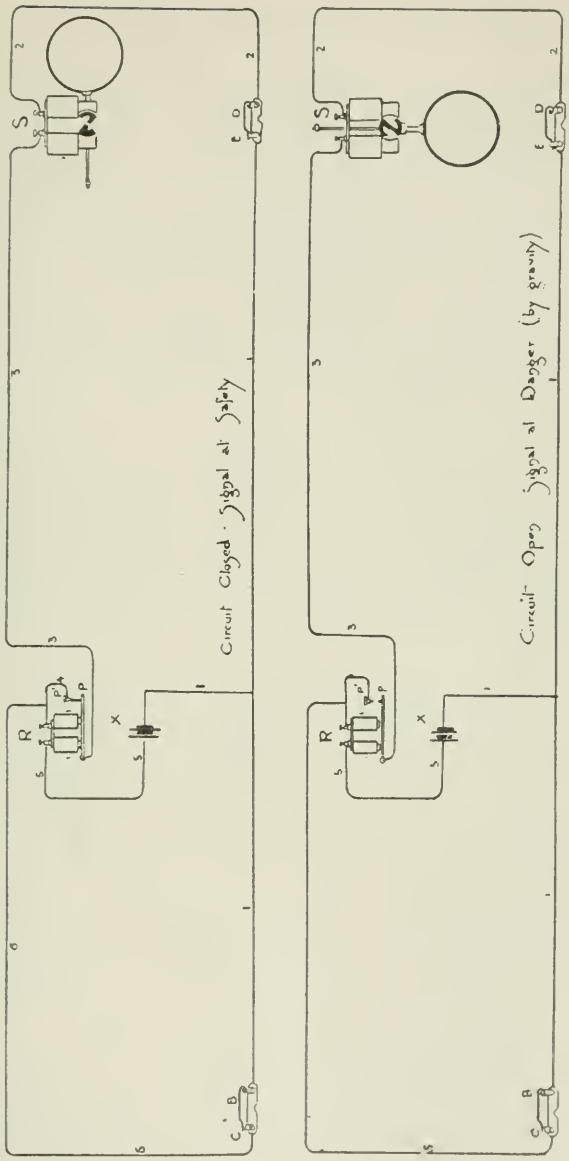

Circuit Closed · Signal at Safety
Circuit Open Signal at Danger (by gravity)
S
R
X
P
C
B
D
E
1
2
3
5
6

Fig - 9

train operates clear track instrument B, which energizes electro-magnet r, thus completing circuit from battery X, wire 1, spring B, anvil C, wire 6, electro-magnet r, wire 5, to battery. This closes contact points p, p^1, but the signal still remains at danger until train has wholly cleared the clear track instrument, on account of the fact of there being two circuits, one through the clear track instrument and relay magnet and another through block track instrument, signal magnet and relay magnet. As the resistance of the latter is much greater than that of the former, the signal will remain at danger as long as clear track instrument spring is in contact with its anvil, which under action of air cushion previously referred to is continuous during passage of train at ordinary speed.

Switches in Signal Circuits.

Any number of switches may be included in a circuit. A misplaced switch, that is a switch set for a siding, causes a break in circuit by operating a switch instrument similar to the track instrument. This causes signal to fall to danger, and as long as the switch is misplaced the signal cannot be cleared.

Single Track Blocking with Disc Signals.

The use of automatic disc signals as described, is calculated for two tracks where trains run always in the same direction on the same track. They may be used equally well, however, for single track blocking. The block sections are arranged to extend from side track to side track. The signals are controlled by electric interlocking and they may be arranged to automatically give the right of way to one train or another but not to both. It is impossible, however, for any mechanical contrivance to choose between a passenger and freight, or between an east bound fast stock train and a west bound train of empty cars.

As automatic signals are confined usually to lines of more than one track where traffic is heavy, their application to single track lines will not be discussed, as most single track lines space their trains by the time interval system, or a system of station blocking.

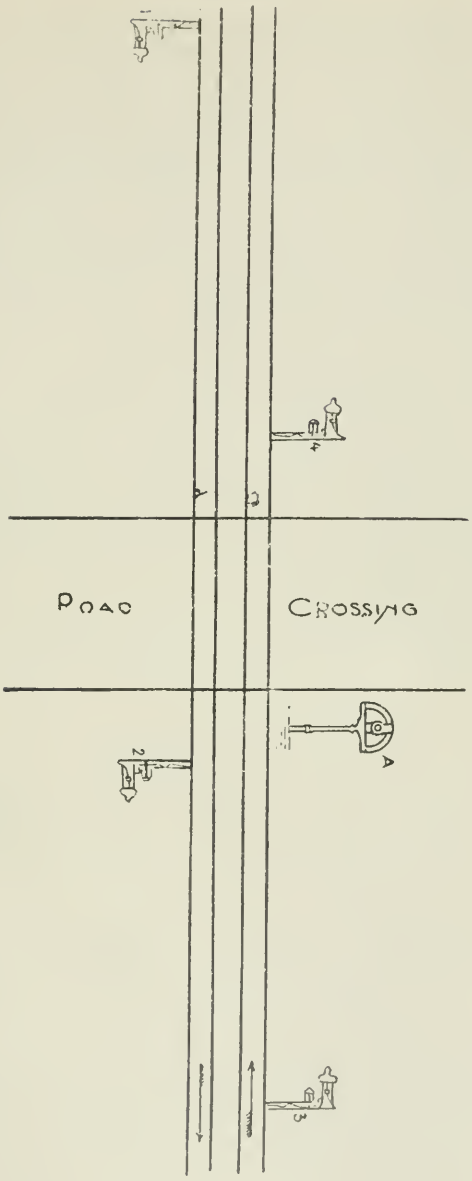


Fig. 10

Audible Highway Crossing Signals.

The track instruments described in connection with the wire circuit system of automatic signals may be used advantageously to give audible warning to pedestrians of passing trains at road crossings. Figure 10 is a plan of signal and track instruments used in connection with a double track. The wire conducting an electric current by means of which an approaching train sets the bell ringing is run to the track instrument, located at any desired distance from the crossing. The circuit is normally open. A west bound train in passing over track instrument 3 closes a circuit and energizes an electro magnet A in an interlocking instrument located together with the battery at the crossing. This closes a local circuit through spring D and its anvil d and starts the bell ringing. The instrument now being locked, the bell continues ringing until train shall have reached instrument 4, which closes a circuit energizing unlocking magnet B, which breaks the contact between spring D and its anvil d, thus opening the bell circuit and silencing the bell.

By an arrangement of interlocking instruments and track instruments the bell may be made to ring by a train approaching from either direction on a single track.

The Electric Semaphore.

The electric semaphore signal to be used in automatic blocking, is the latest development. The claim has been made that disc signals are less distinctive to the eye than semaphores, but this is a matter of dispute. This fact led to many experiments with electrical apparatus to operate a semaphore arm of full size, apparently with success although no extensive installations have been made. The prominent feature of this style of signal is that each has its own independent motive force. An electric motor of about ⅛ H.P. placed in a box attached to the post below the arm, and supplied with current from an Edison-Lalande battery of 10-16 cells, winds a cable on a drum, thereby lifting a counterweight (which holds the signal arm normally at danger), giving the arm the inclined or all clear position. With such a powerful force exerted by motor, and use of a heavy counterweight, difficulties of snow and sleet causing arm to stick is overcome. The

motor has an automatic brake, consisting of a resistance coil, which retards the revolutions of a soft iron circular disc fixed to the armature shaft.

The semaphore blades are same in design as the standard; ball bearings are introduced to eliminate friction. Bells are provided at main line switches, which may only be opened when bells are not ringing. A train in a section to the rear of the one in which a switch is located causes the bell to ring. On the other hand when the switch is opened the signal at entrance to the block is drawn to danger. The signals are operated by track circuits.

Electro-pneumatic Block Signals.

This style of signal has been in use since 1885. They are only used on the busiest portions of lines, usually four track roads, where the sections are short. The power is supplied by compressed air, which flows through valves operated by an electric current. Air compressing plants are established where possible in yards, where they serve the purpose of supplying air for electro-pneumatic systems of interlocking switches, and air for several miles of blocking outside the yard.

The essential parts of the system are:—

(1) The electrical apparatus, consisting of the battery, track relay and connections, and electro-magnet for controlling admission of air to cylinder.

(2) The signal, which is a full-sized semaphore.

(3) A cylinder with piston for moving signal.

(4) An air compressor plant with reservoirs and cooling pipes to precipitate any excess of moisture, and a pipe to convey air under pressure to signals.

The block sections being very short it is found economical and convenient to place two signals on one post, one being the home signal of a section and the other the distant signal of the following section. The former is placed at the top and is of the standard form with a square end. The latter is placed below and has a fish-tail end to distinguish it from the home signal.

On roads of more than two tracks it is usual to define the blocks by signal bridges spanning the tracks, each pair of signals being placed over the track they govern.

This system of automatic blocking is necessarily very costly, owing to the great expense of operating compressor plant, laying of pipe, pneumatic cylinders and electrical apparatus, and this has consequently limited its use to roads where *one* line of pipe will operate the signals of several tracks.

Manual versus Automatic Signaling.

The opinion as to the relative efficiency of manual and automatic systems is divided, even in America. The controlled manual, about which there is a certain amount of automatism on account of the electrical apparatus which makes the setting of signals at the beginning of a block contingent upon that at the end, is operated by human attendants who are not infallible, and liable to error, the result of which may be serious, or slight, or even of no consequence. The element of contingency between the operators eliminates to a great extent any errors made by one. Methods are known to expert operators of "cheating" the machines, by which mistakes may be rectified.

The efficiency of the manual system depends to a great extent upon the operators themselves, some of whom may show a tendency to getting "out of order" themselves once in a while, when duties are light, or, in other words, when the frequency of trains is small, the operator may fall asleep, and although no very serious results may happen, his neglect of duty may cause delay, something which every railroad tries to avoid. Cases have been known where the operator would deliberately prepare for a nap, by getting an unlock from the towermen on each side of him so that he could clear his signals; in which case train must stop at tower in the rear and procure a caution card and then proceed under full control to the tower of the "sleeping beauty."

Such cases could not properly be cited as dangers of the system, but merely defects which may be remedied by the employment of reliable operators. In England, where the controlled manual is practically the only system in use, the record of train

accidents due to misplaced signals is remarkable, a fact which is attributed largely, if not altogether, to the reliability of the operators themselves. It is claimed by English signal engineers that in such a country where there is such extreme heaviness of traffic that the manual is the only system practicable, and this fact along with the highly satisfactory results of such a system accounts for the reluctance on their part, to adopt any system entrusted entirely to mechanical operation.

The disadvantages, apart from expense, inherent in the manual system are few and small. The advantages are manifold. Trains are absolutely spaced and enginemen cannot "run" signals without detection. Permissive blocking is only allowed when apparatus is seriously out of order, which only happens when inspection is poor. If locks fail there is bell communication between towers. If these fail there is the telegraph in complete installations to fall back on. Wrecks, derailments, etc., are easily reported, so that aid may be quickly summoned and trains running on parallel tracks stopped and protected. Any dangerous defects in condition of trains may be noted by towermen and reported to those in advance.

Automatic signals have reached such a stage of perfection that their reliability can no longer be questioned. A million operations of a signal with only one false clear indication, ought to be sufficient to dispel doubt as to their reliability. The efficiency of their working depends almost entirely upon the inspection of the apparatus. The main defect of the automatic signals is that the protection of switches is incomplete. The switches are included in the circuit and have a bell or indicator attachment by which the position of the signal at the beginning of the block is known to the trainmen at the switch. It is possible that trainmen may not observe the indicator, or that the bell may fail to ring by poor adjustment, or by getting broken by mischievous trespassers, so that train using the switch has no warning of another train, which may have already passed the protecting signal and entered the section.

It is sometimes stated that enginemen disregard automatic signals, there being no one to report them. As a matter of fact

this is seldom done. A sane engineman is not going to plunge recklessly into danger when by waiting a specified time at a block signal set at danger, he may then proceed with caution through the block to the next, where he is likely to find the line clear.

The advantages of the automatic system are perhaps not as numerous as those of the manual; a train broken in two is fully protected; broken rails, if rail circuit is used, usually cause signal to go to danger. The former system has decidedly a great advantage over the latter in point of cost, and in this respect it is the most suitable for roads with great mileage and heavy traffic running through open country. The maintenance of both is about the same, but the cost of operation is a factor which does not occur in the automatic, but which is constant in the manual system. For this reason blocks are often too long to give prompt handling of the traffic. With the automatic system the blocks may be made as short as required without materially increasing cost of maintenance, the first cost of installation being practically the only expense to be taken into consideration.

The paramount objection raised by English railroad men against automatic signals of all kinds, is not that they are unsafe, not that they are costly or troublesome in care and maintenance, but rather that the exigencies of heavy traffic prove too much for them thereby causing delay.

The question of the relative merits of the two systems resolves itself into a straight question; which one will operate 100,000 or 1,000,000 times with the least number of unnecessary stoppages of trains. The Railroad Gazette of January 24, 1890, says, referring to the use of a form of automatic signal on a line of heavy traffic: "Going since May 30, 1888, and being used as a positive block signal, it has never got out of order, caused an unnecessary stop, or shown safety when danger existed, thus making a remarkable mechanical record."

Other Systems of Signaling.

There are other schemes by which trains are kept spaced. These are of less importance, being used on roads of light traffic where demands for which handling of trains are not sufficient to

warrant the expense attached to installing complete signal systems. Many roads of light traffic still use the "time interval" as a means of keeping their trains spaced. But the protection of a train that has unexpectedly come to a stop by the ordinary method of sending a man back with a visible or audible signal, is unsafe, except when carried out by men of best judgment. Both the flagman who is to give the signal and trainmen of the following train must never fail to practise the most extreme caution; and as safety is always contingent upon the flagmen having sufficient time to get back to warn following train, another element of danger is introduced. The great deficiencies of this system are all well understood by railroad men. Much of the loss of life, and collisions, are due to ineffective flagging caused by sheer neglect of trainmen to whose judgment is entrusted practically the running of the trains. But while admitting that the time interval system is an unsatisfactory protection for trains, many roads in this country have had to deny themselves the advantages of the block system on account of the cost attached to it.

The Train Staff or Tablet System.

A modified form of the block system is found in the train staff or tablet system. These are exactly the same in principle, the apparatus being somewhat different. It is an old English idea, the track being divided into blocks or sections, and before a train can pass over a block it must have in its possession a metallic tablet or train staff.

The apparatus of the staff system consists of a receptacle for holding a number of metallic staffs, one of which is given to each engineman to authorize him to proceed over a specified length of track. There is a receptacle or "pillar," as it is called, at each end of the block section, and these two are electrically connected or interlocked, so that two staffs cannot be out at the same time. Such a system is only used on single track over short sections.

The sections are laid out varying from 4 to 20 miles in length, according to the distance between towns on the line, a tablet station being established at each.

The electric tablet instrument containing the tablets, is placed at each station which defines the blocks. Before a tablet can be obtained from the instrument at either end of a section, the consent of the operators at each end of the section must be given, and only one tablet can be taken out of the two instruments of a section at a time, so that trains travelling in opposite directions are fully protected.

The tablet is placed in a leather pouch before being handed to the train driver, who, in turn, delivers the tablet for section just travelled. This necessitates trains to come almost to a dead stop before exchanges can be made. Apparatus was invented by which a train running 40 miles an hour could catch up and deliver tablets, thus allowing through trains to proceed without a stop.

The tablet system is sometimes used with the block system where it is desired to suspend the latter temporarily and do permissive blocking. In order to pass a block signal set at danger, it is necessary for the engineman to procure a permissive tablet, which gives him running power over the section protected by the suspended block signal.

Interlocking at Grade Crossings.

A word or two might be said upon the protection of grade crossings. It is done by a system of signals and derailing switches. Experience has taught the best location for the signals, the number, and safeguards necessary in case a train should pass the danger signal.

Figure 11 shows plan of simple grade crossings. Figure 11 (a) represents a single track diamond crossing. The distant signals shown with fish-tail ends are placed 1,200 feet from the home signals, and in each case to the right hand of the track. In case a train should pass a home signal set at danger, the last precaution taken is a derail placed 50 feet from the home signal and about 300 feet from the centre of the diamond.

The signals and derails are operated entirely from a signal tower, there being pipe and wire connections between each and levers in the tower. It is common practice to have the distant

Details shown thus
2 Levers for 4 Switches and 4 locks
6 " " 6 Signals
2 Levers for 4 Switches and 4 locks
6 " " 6 Signals
2 Levers for 4 Switches and 4 locks
6 " " 6 Signals

Fig. 11

signals lock their home signals in the clear position. One lever operates a pair of derails on each track. The signal levers are so interlocked that only one track can have its signals cleared at a time.

The installations for double tracks are obviously as simple as those for single track; in the latter case trains being supposed to run always in the same direction on same track.

Although the high cost of installation and operation has deterred lines from installing these plants, it has been found that the time saved would often warrant the expenditure even on lines of light traffic. In cities where all sorts of crossings are encountered, such plants are an absolute necessity, at any cost. Where track crossings and junctions become complicated, manual power for working the levers is dispensed with in the most recent installations. The use of electricity in combination with compressed air, affords the speediest and most reliable means for handling of trains.

Yard Signaling.

Before concluding these remarks reference might be made to signaling in yards. This is a subject in itself, being one in which difficult problems arise, as in the case of great complications of tracks, where one road crosses another in the vicinity of large yards, or makes junctions or borrows track. Such problems are left for solution to the signal engineer who devises schemes for a systematic operation of switches and signals, the former affording a means of transit from one track to another, the latter protecting trains while performing this operation.

The mechanical side of yard signaling, involving as it does interlocking, is too great to admit of discussion here, so only a few general principles will be referred to.

As the main lines for incoming or outgoing trains are often run through the yards themselves, it is of the greatest importance that signals governing them (main lines) should be absolutely placed. The most common way of placing them is on a light bridge or superstructure, placing signal directly over the track it governs. Where the block system is in use the sections are

short, from one-third to one-half mile in length; signal cabins are placed at the beginning and end of each, where they serve also the purpose of interlocking cabins for main line switches. Each of the cabins has electrical communication between one another, and sometimes between the train starter. As trains run slowly through yards "permissible blocking" is allowed in most cases, there being practically no danger caused by it.

Signals.

The signals are of the semaphore type, distant signals being unnecessary on account of slow speed of trains. They are commonly worked by levers in towers, having pipe and wire connections. The most perfect installations are now operated by the electro-pneumatic system, which, of course, is far superior to hand power levers. It is only in cases of great complication of tracks and switches that these installations are made. The great advantage of the electro-pneumatic system is that signals may be operated at greater distances, and one man can do the work of many in the interlocking towers.

Automatic block signaling may be done advantageously in yards, preferably by the use of compressed air and electricity. One air compressing plant will suffice for the operation of signals of the largest yard. Figure 12 is a cut of a yard whose signals are operated by electro-pneumatic block signals, which stand nominally at danger. The signal bridge in the front of the picture marks the beginning of a section, the two blocks being visibly defined by the two signal bridges in the distance. Interlocking cabins provided with electro-pneumatic levers operate the switch signals and switches. At important road crossings small cabins are built for signal men, whose business it is to operate the gates and give flag warnings.

INDEX TO THE FIRST FOURTEEN NUMBERS.

	Vol.	Page.
Allison, J. L. Transition Curves	ii.	52
Andrewes, E. Notes on the Geology of Rossland Ore Deposits	xiii.	128
Angus, R. W., B.A.Sc. The Gas Engine	x.	61
The Shaft Governor	xi.	76
Ardagh, Arthur G. Peat	xiv.	59
Bain, J. W., B.A.Sc. Planimeters	ix.	15
Notes on Stamp Mill	x.	6
The Accuracy of the Assay of Pyritic Ores	xi.	67
Ball, E. F., A.M. Can. Soc. C.E. Asphalt Pavements	i.	40
Sewers	iii.	39
Water Supply	iv.	60
The Computation of Earthwork and Overhaul by Means of Diagrams	v.	48
Hydraulic Cements	v.	82
Sewage Filtration	vi.	44
Barber, T. Notes on the Development of Water Power	xiii.	189
Blackwood, A. E. President's Address	viii.	1
Description of the Finlayson Marine Pipe Boiler	viii.	189
Bowman, A. M. System of Survey in British Columbia	i.	19
Bowman, H. J., O.L.S. Municipal Engineering in Ontario	x.	177
Bryce, P. H., M.A., M.D. Underground Waters as Sources of Public Water Supplies in Ontario	iv.	15
The Chicago Canal and Some Sanitary Problems connected Therewith	ix.	55
Disposal of Sewerage	xi.	44
Land Drainage in its Sanitary Relations	xii.	119
Principles of Ventilation in their Application to Public Buildings	xiii.	174
Butler, M. J., C.E. Silica Portland Cement	xii.	100
Campbell, A. W., C.E. Roads and Streets in Ontario	x.	14
Road Construction	xi.	18
Pavements	xii.	106
Roadmaking	xiii.	167
Bonding of Broken Stone Roads	xiv.	15

	VOL.	PAGE.
Campbell, G. M. Vice-Work	viii.	33
Carmichael, C. G. Thomson Recording Wattmeter	xiv.	49
Carter, W. E. H. President's Address	xii.	1
Chalmers, J. Double Track Tunnel Hamilton T. H. & B. Railway	ix.	61
Rat Portage Water Works	xii.	85
Chubbuck, L. B. Modern Systems of Interior Wiring	xii.	58
Hydraulic and Electric Elevators	xiii.	91
Chewett, J. H., C.E. The Removal and Destruction of Garbage	vii.	11
Christie, Fred. W., C.E. Gold Mining in Nova Scotia	xi.	129
Coleman, Prof. A. P., M.A., Ph. D. Mount Brown and the Sources of the Athabasca	vii.	62
Connor, W. A., B.A. Solutions	viii.	223
Corrigan, G. D. Modern Copper Smelting	iv.	100
Davidson, J. L. Location and Construction of Crow's Nest Pass Railway	xii.	135
Deacon, T. R. North Bay Water Works	vi.	91
DeCew, J. A. Chemical Wood Pulp	xiv.	6
Dobie, J. S., Grad. S. P. S. The Action of Heat on Cement	ix.	126
Duff, J. A., B.A. Presidential Address	iii.	82
The Fundamental Principles of Dynamics	v.	27
Diagrams	v.	61
The Country Roads of Ontario	viii.	49
Tests on Tensile Strength of Steel Boiler Plate	x.	184
Neely's Formula for the Strength of Wooden Beams	xii.	194
Elliott, H. P., B.A.Sc. Lightning Arresters	ix.	13
A Discussion of the Considerations Affecting the Cost of Electric Power	xi.	113
Ellis, W. H., M.A., M.B. Junker's Gas Calorimeter	xii.	143
Fire Making	xiii.	201
Foreman, W. E. Air Brakes	xiv.	133
Galbraith, Prof. Technical Education	v.	100
Goodwin, J. B., B.A.Sc. Tunnel at Niagara for Development of Power	vi.	34
Niagara Falls Sewerage System	x.	38

VOL. PAGE.

Gray, R. A. L. Power Switchboard and Dynamo Tending ..... viii. 201
Greenwood, H. F., C.E. Concrete on Trent Valley Canal. x. 80
Gurney, Cromwell, Illustrative Casualties in the Workshop ..... ix. 8
Haight, H. V. Gear Cutting ..... viii. 178
Standards in Machine Shop Practice ..... ix. 38
Air Compressors ..... x. 123
Hare, W. A. The Process of Manufacturing Mechanical Wood Pulp ..... xii. 12
The Problem of Speed Regulation in Plants Driven by Water Power ..... xiii. 37
Harkness, A. H. Crushing Strength of White Pine.... x. 180
Harvey, C. J., C.E. The Conjunction of the Nineteenth and Twentieth Centuries from an Engineering Standpoint ..... xii. 156
Haultain, H. E. T. Presidential Address ..... iii. 11
Extract from Letter from ..... iii. 109
Some Experiences with a Canadian Turbine in Austria ..... vi. 83
Hemphill, W. Construction of the Hamilton Cataract Power Company's Plant at DeCew Falls.... xii. 76
Ratio of the Cylinders of a Compound Engine and what takes Place in Them ..... xiv. 31
Innes, W. L., C.E. Grading ..... viii. 5
A Brief History of Astronomy ..... ix. 26
James, D. D. Surveying in the City and Suburbs of Toronto ..... iii. 57
Johnson, S. M. The Maintenance of English Roads... viii. 17
Brickwork Masonry ..... ix. 153
Kennedy, J. H., C.E. Reference Points and Bench Marks ..... i. 27
Laing, A. T., B.A.Sc. The Waterworks System of Amherstburg and Essex ..... v. 55
Laing's Planetarium ..... ix. 138
Latham, R. Signaling ..... xiv. 163

	VOL.	PAGE.
Laschinger, E. J. Hirn's Analysis of Heat Distribution in the Cylinder of a Steam Engine	viii.	120
Lea, W. A. Photography	iv.	82
President's Address	vi.	1
Leask, W. Corrugations on Mill Rollers	iii.	63
Lott, A. E. A Re-Survey in Ontario.	i.	24
Notes from an Engineer's Pocket Book	xii.	145
Ludgate, B. A. Problems from an Engineer's Pocket Book	xii.	145
MacDougall, A., C.E. Professional Prospects	vii.	7
McAree, J., O.L.S., D.T.S. The Crawford Gold Mine.	vii.	26
McCulloch, A. L. Mortars and Cements	ii.	25
McDowell, R. Foundations	iv.	54
McFarlen, T. J. The Nickel Mining and Smelting Industry of Sudbury	vi.	48
McKinnon, H. L. The Cleaning and Annealing of Castings	viii.	132
McLennan, J. C., B.A. Roentgen Radiation	ix.	142
MacNabb, J. C., O.L.S. Proposed St. Clair and Erie Canal	vii.	62
McPherson, A. J., B.A.Sc. Specifications for Sidewalks.	x.	20
Marani, C. J. Historical Review of Sanitary Science and the "Germ Theory."	iii.	20
The Separate System and the Brockville Sewers.	iv.	36
Sanitary Plumbing	v.	7
Marani, V. G. A Short, Practical Essay on "The Sea and Its Waves."	v.	73
Merrill, E. B., B.A., B.A.Sc. Electric Traction as Applied to the Street Railway	vi.	57
Dynamo Design	viii.	205
Mickle, G. R. Freiberg Smelting Process	iv.	89
The Value of Undeveloped Mineral Claims	xii.	181
Minty, W. M., B.A.Sc. Notes on the Relation of the Mechanical Properties of Steel to the Chemical Composition	xi.	145
Mitchell, C. H., B.A.Sc. Earthworks on Roads and Railroads	v.	37
Triangulation Survey	vi.	23
Aerial Mechanical Flight	viii.	71
The Conservation of Water for Power Purposes.	xiv.	61

	VOL.	PAGE.
Monds, W. Circulation in Water Tube Boilers	xiii.	112
Morris, J. L., C.E. Masonry Foundations	iii.	52
Retracing Old Compass Lines	v.	70
Mundie, W. B., F.A.I.A. The High Building Problem	x.	28
Neelands, E. V. Some Adventures on the Abitibi	xii.	149
Mine Timbering	xiii.	137
Some Notes on Greater Ontario	xiv.	81
Newman, W. The Drainage System in Essex and Kent	iv.	79
Palmer, R. K. Some Notes on Bridge Drafting	xiii.	119
Pedder, J. R., O.L.S. The Beeton Waterworks System	vii.	18
Raymer, A. R. Railway Surveys	ii.	34
Richardson, G. H. Rodding on Railway Work	ii.	9
Richards, E. The High Pressure Steam Boiler	xii.	9
Cold Storage	xiii.	76
Rosebrugh, T. R., B.A. Scale Calculus	iii.	48
Ross, D. A., B.A. Railroad Location in the Crow's Nest Pass Railway	xii.	29
Russell, S. Track Laying	iii.	73
Offsetts from Tangent on a 1° Curve	iii.	111
Notes on Railway Location and Construction in the North-West	iv.	42
Russell, W. Township Survey	iii.	98
Scott, A. M., '96 Arts. The Pendulum	ix.	81
Shanks, T. President's Address	xiii.	1
Shields, J. D. President's Address	vii.	11
Shillinglaw, W. H. Hot Water Heating	v.	20
Shipe, E. F. The Hardening and Tempering of Steel	viii.	169
Smith, C. B., Ma.E. Canadian Steam Railways	xiii.	158
Smith, Alexander H. Exploring New Ontario	xiv.	22
Southworth, T. Forestry	xii.	114
Speller, F. N., B.A.Sc. Asphalt and Asphalt Paving	vii.	44
The Use of Asphalt in Engineering Construction	viii.	150
The Modern Open-Hearth Process	xi.	5
Stern, E. W. Notes on Field Work of Railroad Construction	i.	9
Notes on Iron Bridge Building	ii.	44
Cable Railways	iii.	36

VOL. PAGE.

Stewart, L. B., D.T.S. Description of a Timber Limit Survey in the Rocky Mountains ..... iii. 68
Distance Measuring Micrometers ..... iii. 92
An Exploratory Trip Through the Rockies ..... vi. 96
A Canoe Trip on the Saskatchewan ..... vii. 74
A Single Form of Telemeter ..... ix. 148
Longitude by Lunar Distances ..... xi. 53
A Trip to the Yukon ..... xiii. 145
Stovel, H. R. Hints to Prospectors ..... xii. 177
Cement vs. Bone Ash Cupels ..... xiv. 56
Stull, W. W. History and Chemistry of the Cyanide Process ..... xi. 25
Tennant, D. C. Tensile Strength of Rivets and Bolts.. xiii. 206
Thomson, R. W., B.A.Sc. President's Address..... v. 1
Sewage Disposal in Ontario ..... viii. 194
Thomson, T. K., C.E., A.M. Can. Soc. C.E. Angle Blocks. ii. 50
Bridge Specifications ..... vi. 5
Notes on Cement ..... vii. 36
Foundations for a Twenty-one Story Building.... x. 96
Thorold, F. W. Electrolysis ..... xii. 72
Presidential Address ..... xiv. 1
Tye, A. T. The Canadian Dawn Animal ..... viii. 138
Tye, W. F. Cross Sectioning ..... i. 31
Tyrrell, H. G. Explorations on the Battle River ..... ii. 20
Madison Draw Bridge at Portland, Oregon .... xiv. 89
Tyrrell, J. W., C.E. Hydraulic Mining in British Columbia x. 88
On Snowshoes from the Barren Lands ..... x. 104
Van Buskirk, W. F., A.M., Can. Soc. C.E. The Ventilation of Sewers ..... viii. 128
Wagner, W. E. Aerial Cableways ..... xiii. 10
Withrow, W. J. Petroleum ..... ix. 38
Handling Daylight ..... xiv. 124
Wright, C. H. C., B.A.Sc. Aspect and Prospect ..... ix. 134
The Strength of Glass ..... xiii. 221

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